Mark Cantley

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HOUSE OF COMMONS

Sixth Report from the

EDUCATION, SCIENCE AND ARTS COMMITTEE

Session 1981–82

BIOTECHNOLOGY: INTERIM REPORT ON THE PROTECTION OF THE RESEARCH BASE IN BIOTECHNOLOGY

Together with Appendices

Ordered by The House of Commons *to be printed*

27 July 1982

LONDON

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The Education, Science and Arts Committee is appointed under S.O. No. 86A to examine the expenditure, administration and policy of the Department of Education and Science and associated public bodies and similar matters within the responsibilities of the Secretary of State for Northern Ireland.

The Committee consists of nine members, of whom the quorum is three. Unless the House otherwise orders, all Members nominated to the Committee continue to be members of it for the remainder of the Parliament.

The Committee has power:

(*a*) to send for persons, papers and records, to sit notwithstanding any adjournment of the House, to adjourn from place to place, and to report from time to time;

(*b*) to appoint persons with technical knowledge either to supply information which is not readily available or to elucidate matters of complexity within the committee's order of reference.

The following were members of the Committee during the present inquiry:

Mr Christopher Price (Chairman)

Mr Tim Brinton	Mr David Madel
Mr Patrick Cormack	Mr John McWilliam
Mr Martin Flannery	Mr John Osborn
Mr Harry Greenway	Mr Dafydd Thomas

Changes in Committee membership—Session 1981–82:

20 November 1981

Mr Stan Thorne *discharged,* Mr Martin Flannery *added.*

The cost of printing and publishing this Volume is estimated by Her Majesty's Stationery Office at £11,484.

TABLE OF CONTENTS

NOTES

1. The evidence on which this inquiry is based is contained in the Minutes of Evidence published separately after each session (Education, Science and Arts Committee, Session 1981–2, *Biotechnology, Minutes of Evidence*) between 24 March and 26 May 1982 as HC papers (1981–82) 289-i to 289-vii. References in the text to questions in this evidence are indicated by the letter "Q" followed by the number of the question: references to memoranda by "Ev" followed by the page number. References to Appendices are given by "Appendix" followed by the page number.

2. The individual replies to the Questionnaires sent out by the Committee have not been printed, though the Report includes some references to them. (See note 2 on p. xxii.) An analysis of the Questionnaires is included at Annex 1. Copies of the individual replies are available for inspection in the Committee Office. Application should be made to the Clerk to the Committee. For the convenience of Members copies have been placed in the Library of the House.

LIST OF ABBREVIATIONS

ABRC	Advisory Board for the Research Councils
ACARD	Advisory Council for Applied Research and Development
ARC	Agricultural Research Council
BTG	British Technology Group
CAMR	Centre for Applied Microbiology and Research
CASE	Co-operative Awards in Science and Engineering
CBI	Confederation of British Industry
CPRS	Central Policy Review Staff
DES	Department of Education and Science
DOI	Department of Industry
HORC	Heads of Research Councils
IRCCCOB	Inter-Research Council Co-ordinating Committee on Biotechnology
MRC	Medical Research Council
MRE	Microbiological Research Establishment
NAB	National Advisory Body for Local Authority Higher Education
NEB	National Enterprise Board
NERC	Natural Environment Research Council
NRDC	National Research Development Corporation
SERC	Science and Engineering Research Council
TDC	Technical Development Capital
UGC	University Grants Committee

SIXTH REPORT

The Education, Science and Arts Committee have agreed the following Report:

BIOTECHNOLOGY: INTERIM REPORT ON THE PROTECTION OF THE RESEARCH BASE

SECTION 1: INTRODUCTION

1.1. The decision of your Committee to undertake an inquiry into biotechnology[1] stems, in part, from an incomplete inquiry of the former Select Committee on Science and Technology. The need for an urgent Interim Report became apparent later. The history is as follows.

1.2. On 3 April 1979 the Genetic Engineering Sub-Committee of the Select Committee on Science and Technology, who were engaged on an inquiry into Recombinant DNA (dexoyribonucleic acid) Research, although they had not concluded their work, decided in view of the impending General Election to make an interim Report.[2] This Report was confined to examining the public policy issues raised by the creation of novel genetic material by recombinant techniques, the industrial production and utilisation of organisms containing recombinant DNA and the import, export, and distribution within the United Kingdom of such organisms.[3]

1.3. The Sub-Committee were surprised to find that the Department of Education and Science (DES) was the lead department for genetic engineering.[4]

1.4. The Sub-Committee received evidence to suggest that considerable potential benefit could be achieved by the industrial exploitation of recombinant DNA technology, and emphasised that UK researchers and companies were in the forefront of technical developments.

1.5. The Sub-Committee expressed the hope "that a Select Committee on Science and Technology will be established in the next Parliament and that the Committee will continue this inquiry", on which they regretted that they had been "unable to take all the evidence to come to conclusions".

1.6. However, after the General Election of 1979, the next Parliament established a new system of Select Committees. Since the Genetic Engineering Sub-Committee of the former Science and Technology Committee had established that the DES was the lead department in the field of their inquiry, we undertook the responsibility for continuing this work.

1.7. In our discussions about the inquiry we realised that the scene had changed: the relative importance of the several public policy issues that had concerned our predecessors in 1979 had altered, and we felt that a broader inquiry into biotechnology was now required.

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[1]We have found the following definition generally acceptable: "the application of biological organisms, systems or processes to manufacturing industry". For the source and an elaboration of this concise definition see Section 2, paras. 2.2 to 2.6, below.

[2]HC 355, Session 1978–79.

[3]*Op. cit.* para. 4.

[4]*Ibid.* para 11.

1.8. Before taking evidence we arranged informal meetings with the Royal Society, with scientists from the Science and Engineering Research Council (SERC), the Medical Research Council (MRC), the Agricultural Research Council (ARC), and Imperial Chemical Industries Ltd. (ICI).

1.9. We came to the view that first, an urgent report was needed to secure, from government and industrial sources, adequate financing for the continuation of the basic research in which Britain was a world leader; and after this, a wide-ranging study of the exploitation by this country's industry, in collaboration as appropriate with overseas interests, of the opportunities indicated by the researchers. We are well aware that most of the research in biotechnology is taking place in universities. We are also aware that it takes place in a small number of polytechnics and other teaching institutions. We hope our recommendations regarding the University Grants Committee (UGC), will be read as applying also to the National Advisory Body for Local Authority Higher Education (NAB), where appropriate.

1.10. This Report, therefore, is an interim report particularly directed towards the protection of biotechnology in academic institutions and to those responsible for them. We intend to follow it up with a wider study of the future of biotechnology.

1.11. Between March and May 1982 the Committee heard oral evidence, supported by memoranda and published in daily parts,[1] from the organisations and individuals listed on page liv.

1.12. The Committee received 30 written submissions, and 15 answers to a questionnaire on biotechnology that the Committee sent out. An analysis of the replies to the questionnaire, together with the names of those who responded, is at Annex 1.

1.13. We take this opportunity to thank our specialist advisers, Professor William Brammar, BSc, PhD, Professor of Biochemistry, University of Leicester: Dr Ian Campbell, BSc, Lecturer in Genetics, University of Edinburgh, and Mr Michael Shattock MA, Academic Registrar, University of Warwick, from whom, together with Dr John Poole, MA, the Head of the Scientific Section of the House of Commons Library, we have received invaluable help in this interim inquiry.

SECTION 2: THE IMPORTANCE OF BIOTECHNOLOGY

Definition

2.1. Over the past two or three years biotechnology has risen in public awareness with a rapidity comparable to that achieved in the mid 1970s by microelectronics. The analogy is persuasive but at the same time could be misleading in that it may give rise to expectations that biotechnology may develop at the same pace as microelectronics has done.

2.2. The novelty of the subject is well illustrated by the fact that none but the newest dictionaries are likely to include the word itself in its current sense. (Thus Chambers's Dictionary of Science and Technology, 1974 edition, includes biotechnology as a synonym of ergonomics.) There is not yet unanimity on what

[1]See note 1 on p iii above.

biotechnology comprises, but throughout this inquiry we have found the definition used in the Spinks report, so named after the chairman of the working party who produced it,[1] to be adequate and generally acceptable to those who have given us oral or written evidence.

2.3. The Spinks Committee defined biotechnology as "the application of biological organisms, systems or processes to manufacturing industry". Biotechnological processes have generally involved the use of micro-organisms, including bacteria, yeasts and fungi, or products derived from these organisms, to carry out biological reactions. Recent developments in cell-culture techniques have allowed cells derived from animals and plants to be similarly used. The cultured organisms can be harvested for use as a foodstuff, can be used to carry out a conversion, such as that of sugar into alcohol for the drinks industry, or can act as a source of biologically active molecules, such as an enzyme or an antibiotic. Rapid advances in cell and molecular biology, especially the development of methods for the manipulation of genes and their transfer between organisms, have led to the potential for completely novel industrial processes. Parallel developments in process engineering, control engineering and fermentation technology have amplified the prospectus of a biologically based industrial revolution.

2.4. In addition to technological advances, a second major stimulus to biotechnology comes from changes in the economic climate. The escalation of oil prices since 1973, with the associated increased awareness of the finite nature of fossil fuels and other resources, together with the improved living standards of some Third World countries, have led to a growing need for cheaper and more secure supplies of energy and chemical feedstocks, as well as an increased demand for agrochemicals and the products of the pharmaceutical industry.

2.5. The importance of biotechnology is that it appears certain to be an area of exciting expansion and opportunity, pervading many sectors of industry, including agriculture, (plant cell culture was singled out by Spinks as one of the key areas of particular potential), food and feedstuffs, chemical, pharmaceutical, energy and water industries. It can confidently be expected to play a substantial role in the production of new drugs, vaccines, hormones and antibiotics; cheaper and more secure supplies of energy and chemical feed-stocks; more efficient production, storage and distribution of foodstuffs; and improved environmental control and waste management. An important consideration is that it will largely be based on renewable and recyclable materials and therefore suited to the needs of a world in which energy is expensive and scarce.

2.6. Two conclusions immediately follow from our original definition: first, that biotechnology itself embraces a wide range of disciplines and subjects, and, second, that the term applies to processes that have been used in the past, as well as those developed now and in the future.[2]

[1] *Biotechnology: Report of a Joint Working Party*. Advisory Council for Applied Research and Development (ACARD), Advisory Board for the Research Councils (ABRC), and the Royal Society. HMSO, March 1980. Hereafter "Spinks". We regret the death of Dr Spinks in the year after this report was published.

[2] Useful summaries which we have drawn upon here are given in *Patterns of Change in Biotechnology*. P K Marstrand, SPRU, University of Sussex, June 1981, and *Biotechnology*, Laing and Cruickshank, London, March 1982.

Historical Development

2.7. We deal with the first point later at greater length but, to put current concern into context, it is useful to review the development of biotechnology up to the present.

2.8. In some ways the products and processes that now form a part of what is understood as biotechnology are probably as old as man's experience of communal living. Activities such as baking, brewing and wine making are known to date back several millenia. The discovery of these and similar processes, such as cheese, yoghurt and vinegar making, must be the result of accidental observation or intuitive experimentation and subsequent application. Nevertheless, they do represent the beginnings of man's recognition that he can adapt and appropriate biological processes for his own purposes and needs.

2.9. Changes there undoubtedly were between such ancient and modern times, but they would be of the type characteristic of the slow development of craft-based practices lacking a scientific basis.

2.10. The idea that biological processes were effected by organisms such as yeasts was proposed by van Leeuwenhoek in the 17th century, but not generally accepted until Pasteur carried out his work on fermentation in the late 19th century. Microbiology may date its modern beginnings from this time and, coincidentally, so do genetics since contemporaneously with Pasteur, Gregor Mendel was carrying out his fundamental work on heredity.

2.11. Industrially biotechnology began to emerge at the very end of the 19th century with, first the use of fermentation methods to produce food substances such as lactic acid, then industrial alcohol, glycerol, and solvents such as acetone. Not for the first time war was a great stimulus to invention when customary raw materials were difficult to obtain.

2.12. With the end of the first world war came the beginning of the age of cheap motoring. For every gallon of petroleum produced by the world's refineries nearly three times as much of nearly worthless by-products were obtained. From the efforts of the oil companies to find uses for these heavier fractions stem the modern petrochemical industry known to all for its plastics, detergents and agricultural chemicals. Only now are there signs that this industry may be beginning to move away from the feedstocks that have powered it for half a century and more.

2.13. Thus the dawn of the petroleum age caused the eclipse of the newly emergent biotechnology. Its rebirth occurred about 40 years ago with the beginning of large-scale penicillin production, together with that of vitamins and enzymes. Nearer the present a wider range of materials has begun to appear, prepared by similar techniques, such as amino acids, vaccines, insecticides and food flavourings.

Biotechnology Today

2.14. In a paper to the Parliamentary and Scientific Committee[1] the late Dr Alfred Spinks summarised what he saw as the "five new developments [that] were likely to expand the power and versatility of biotechnology beyond anything previously possible":

[1]Delivered at the House of Commons, 20 January 1981.

(a) New developments in continuous fermentation and fermenter design;

(b) Novel chemical engineering approaches to large-scale fermentation;

(c) Increasing knowledge of how to handle enzymes and bacterial and fungal cells;

(d) Better ability to handle plant and animal cells in tissue cultures;

(e) Genetic manipulation.

2.15. It is, of course, the last area that has most strongly caught the public imagination and produced the largest amount of speculative venture capital. It would be highly misleading to concentrate on this single aspect to the exclusion of others in this multi-faceted industry. This is well illustrated by Table 1 below which shows the make-up of the UK's fermentation capacity.

Table 1: Total UK Fermentation Capacity

Product	*Total capacity (cubic metres)*
Waste water	2,800,000
Beer	128,000
Antibiotics	10,500
Cheese	3,000
Baker's yeast	19,000
Bread*	700

*Bread not made by the quick Chorleywood system which does without the traditional long dough fermentation; 75 per cent of British bread is now Chorleywood.
"Biotechnology and Industry." P. Dunnill, *Chemistry and Industry,* 4 April 1981, p. 204.

In other words, the biological treatment of waste water accounts for no less than 95.0 per cent of this total, food and drink for 4.6 per cent and antibiotics manufacture for only 0.4 per cent. The fact that water treatment is usually thought of as a municipal enterprise, and indeed it may not figure greatly in the revolution now expected, does not lessen its importance overall.

2.16. Alternatively, we may look at the output of the present biotechnology industry. Table 2 shows the sales in 1979 of the UK fermentation industry:

Table 2: UK fermentation industry sales in 1979

Industry	*Sales (£m)*
Brewing	3,190
Spirits	1,860
Sewage	560
Cheese	415
Cider, wine	190
Bread*	150
Antibiotics	100
Yoghurt	65
Yeast	25
Citric Acid	20

*Non-Chorleywood.
Dunnill, *op. cit.*

In that same year these industries accounted for 4.5 per cent of total UK manufacturing industry sales.

2.17. Thus biotechnology is already important in the British economy, but as yet the results of genetic manipulation have not contributed much to it. Dr James of the SERC told us: "We have recently come back from a visit to Japan where Professor Beppo, one of the major biotechnologists in Japan, began his talk by saying, 'Nobody has made a penny out of recombinant DNA yet'."[1]

The future of biotechnology

2.18. It has been made repeatedly clear to us that the future is not expected to be a simple extension of the present. A number of factors will be responsible for this:

(a) The availability of raw materials from renewable and recyclable resources and, in particular, of substitutes for oil;

(b) The prospect that biotechnological processes are becoming more economic to perform as a result of advances in chemical engineering and control technology;

(c) The realisation of the potency of genetic engineering for modification of enzymes, plant and animal cells and other organisms.[2]

2.19. On this last point the Spinks report said:

> "Rapid advances in both cell and molecular biology have allowed more confident prediction that a given product can be produced by a biological process or organism at a reasonable cost. Genetic manipulation, involving the transfer of genetic material from one organism to another and giving the recipient some desired characteristic of the donor, has become a practical and quite general proposition. As a result, a rational rather than empirical approach to biotechnology is now feasible, with organisms tailored to specific needs and process conditions." (para. 2.1.)

2.20. These developments are not expected to follow a uniform path. The Brewing Research Foundation sub-divided the subject, not by application nor end use, but by areas according to the expected scale of industrial development required:

(a) Large scale, where biotechnology must compete at first with oil as a raw material and subsequently with coal;

(b) Medium scale, where biotechnology must compete with petroleum-style technology (but not necessarily using liquid fossil fuel as feedstock) to produce currently used commodity chemicals or substitutes for them, and with agriculture to yield desirable natural products;

(c) Small scale, where specifically biochemical products are obtained by routes for which no equally economic routes can be foreseen at present.

2.21. The Foundation feel, and others appear to agree with them, that the large and the medium scale applications are probably not currently economically viable; the few exceptions are alcoholic drinks, and some organic acids, including acetic acid (vinegar) for human consumption.

[1]Q. 264.
[2]See Appendix 5, Memorandum from the Brewing Research Foundation Research Establishment.

2.22. Two large volume commodities illustrate these exceptions and the problems associated with them. The first is single cell protein, in which a number of oil companies became interested in the 1960s and 1970s. This is derived from hydrocarbons by the use of micro-organisms and is used as an animal feedstuff supplement. The low cost of soya and the increasing cost of oil deterred a number of companies, but ICI persevered and now produce 50-70,000 tonnes of their own material (Pruteen) from methanol. The product may still not be competitive but its manufacture has helped to establish ICI's reputation. The second commodity is corn syrup which Spinks instanced as an example of the adverse effects of European Community policies in this new area. We quote from the report (para. 3.29.):

> "As an example, we would cite the development in the United Kingdom of an efficient immobilised enzyme process for converting maize starch into a sweet syrup (isoglucose) that competes effectively with sugar for many food processes. Although this process promises new markets for maize farmers in the EEC, levies on the new product designed to protect sugar beet farmers have resulted in one firm in the United Kingdom going out of business, and the development and use of an alternative sweetener and preservative being inhibited. The business remains profitable in the United States where the technology will doubtless be further developed."

2.23. However, whatever the prospects in these two classes of production may be now, the coming years are expected to see big changes, granted that manufacturers can expect their enterprises to be profitable and reasonably free from the external vagaries of the market. Among them are energy applications such as the production of alcohol fuels (ethanol and methanol), wastes treatment, and agriculture (agrochemicals, crop improvement, plant cell cloning and nitrogen fixation). Some authorities believe that in the long run these areas may have the biggest impact on the world economy.

2.24. Products made on a small scale are unlikely to be affected by such factors. Progress and profits in the foreseeable future are expected to be made in this area. This potential of biotechnology is well illustrated by two historical examples: in 1949 the cost of cortisone was slashed from US $200 a gram to 68 cents, a reduction of 99·6 per cent, by the discovery of a biological route for its manufacture, and, secondly, the annual sales of the cephalosporin antibiotics, research on which was supported for several years by the National Research Development Corporation (NRDC), now total £1,100 million world-wide.[1]

2.25. As these illustrations show, prime among the small-scale products which informed opinion expects to show particular promise are those used in health care.[2] Examples are: human insulin, antibiotics, vaccines (e.g., for hepatitis, malaria, rabies and influenza), interferons (anti-viral agents), human growth hormone (to cure dwarfism arising from pituitary gland deficiencies) monoclonal antibodies (which have a wide range of applications in analysis, diagnosis and therapeutics), blood products (to make up for the deficiencies in the blood donor system; UK currently imports 50 per cent of its needs), and, finally, animal pharmaceuticals (growth hormones, vaccines and anti-parasitic agents). The last may prove to be more important in the short run than products intended for human use since the market is not subject to the same control regimes.

[1]Ev. p. 41, para. 6.
[2]See the responses to question no. 1 of questionnaire at Annex 1.

2.26. While nearly all commentators agree that the prospects are bright, they are equally agreed that they will not come quickly or easily. Spinks looked to the end of the present decade; Prutec Ltd spoke of a 20-year period before the market launch of a major development[1] and followed this up in their oral evidence, as did also the British Technology Group (BTG) and Technical Development Capital (TDC);[2] the Department of Industry in its submission counselled patience and mentioned 20 years,[3] and the Secretary of State for Industry urged the need for "patient investment" and pointed out that "the economics do not at the moment begin to look attractive".[4]

Section 3: Biotechnology in Britain: Past and Present

The evolution of British biotechnology

3.1. As the Royal Society's recent report on the educational implications of the surge in interest in biotechnology[5] points out, the subject is commonly linked in the public mind with the promises and threats of genetic engineering. The association is only strengthened by the awareness of the mushroom-like emergence of a number of companies in the USA, such as Genentech and Cetus, active in this area of research and with enormous stock market valuations. This view fosters the belief both that this is the growing point and that, since these new companies tend not to be British, this country may have once more missed a golden opportunity for future wealth creation.

3.2. The first belief may ultimately prove to be true but the second is assuredly not yet so. It is the fear that Britain is in danger of missing this opportunity that prompted your Committee to undertake this inquiry.

3.3. As we have seen, until about a century ago biotechnology must be considered as a number of craft-based enterprises, often conducted on a scale no bigger than the domestic one. With the growth of science and technology there came an ever increasing flow of discoveries and innovations that have gradually helped to mould the subject into its present shape.

3.4. The British have been influential in this transformation. Thus in 1843 the world's first agricultural experimental station was opened at Rothamsted: the work here first demonstrated the importance of soil micro-organisms. In 1912 Britain developed the activated sludge treatment of sewage. In 1923 J J R MacLeod and his co-workers won a Nobel Prize for their work on the isolation of insulin, and in 1958 F Sanger won one for his determination of its structure. Sanger shared a second Nobel Prize in 1980 for related work on the structure of DNA, and Crick, Wilkins and the American, Watson had won a Prize in 1962 for their work on the double helical structure of the molecule.

3.5. In 1928 Sir Alexander Fleming discovered penicillin and Glaxo introduced its large scale manufacture here in 1946. From the late 1950s Beechams began the development of a series of modified penicillins. In the same decade other important

[1]Ev. p. 47.
[2]Qs. 141–9.
[3]Ev. p. 114.
[4]Q. 339.
[5]*Biotechnology and Education.* The Royal Society, November 1981, para 7.

drugs began to come into prominence. The cephalosporin antibiotics were first isolated in 1953 at Oxford and four years later Isaacs discovered the anti-viral interferon. The Wellcome Foundation has been working on their manufacture since 1974. A year later Milstein and his colleagues at Cambridge prepared the first monoclonal antibodies; the British company Sera-Lab was the first in the world to produce them commercially in 1978.

3.6. The Agricultural Research Council (ARC) first produced foot-and-mouth vaccines by cell culture methods in 1961 and another ARC unit isolated the virus that causes Marek's disease in poultry in 1967 and went on to produce the first vaccine for it two years later.

3.7. A Unigate subsidiary developed around 1950 a safe, bacterially-derived, food preservative (Nisin) and has a substantial export market for it. Tate & Lyle have long been working on the conversion of carbohydrate feedstocks into chemicals by the use of fermentation and enzyme technology, and the same company developed the technique of immobilising enzymes so that they are reusable.

3.8. The production of single cell protein was pioneered by British Petroleum and later by ICI who began large scale manufacture in 1980. Another process has been developed by Rank Hovis McDougall to yield a protein approved for human, as distinct from animal, use.

3.9. Finally mention must be made of Unilever's work on cloned oil palm trees by cell culture. By this means plant variability is reduced and the quality of the resulting edible oil is ensured.

3.10. By any standards this is a record of achievement to be proud of. Do the auguries indicate that it can be maintained?

The growth of national concern

3.11. The Spinks Report provided and continues more than two years after its publication to provide a focus for concern and attention. The fact that it was the joint compilation of three of the most influential science-policy making bodies in the country gives its words substantial weight.

3.12. The Spinks Report does not, however, mention an even earlier paper by Sir Harold Hartley, Scientific Adviser to the CEGB 1967[1], which he presented to the then Ministry of Technology in 1967 urging the development of biotechnology, although it could almost have appropriated Sir Harold's words:[2]

> "Successful development depends on the intimate cooperation of the microbiologist, the geneticist, the biochemist, and of the chemical and control engineers. It must take place at universities in order to attract and train the young men and women who will be needed in these industries of the future. We have the ability and enthusiasts if they are given support on an adequate scale for the complex operations involved. What we need now are two or three strong centres of teaching and research directed specifically to industrial microbiology in order to safeguard the future of the industries in this country. Now is the time to retrieve the position that has been allowed to slip."

The Committee have received no evidence that anything was done in response to this need.

[1]Director of Research for LMS Railway 1930–45; Chairman, BEA 1946; Chairman, BOAC 1947; President of the Institution of Chemical Engineers 1951–52 and 1955–56.

[2]Quoted in *Process Biochemistry*, April, 1967, p. 3.

3.13. That the Advisory Council for Applied Research and Development (ACARD) and the Advisory Board for the Research Councils (ABRC) were to carry out a joint study (to become known as the Spinks Report) was announced by Mrs Williams, the then Secretary of State for Education and Science on 13 December 1978.[1] Subsequently the Royal Society joined in the study. When the report appeared in March 1980 it was revealed as a thorough review of the present scale of support for biotechnology in the UK, together with comparisons with five other countries, a consideration of the opportunities it offers the country and an examination of the current constraints and shortcomings, and finally a detailed plan of action.

3.14. The Spinks Report made a dozen primary recommendations and as many again that they regarded as somewhat less important.[2] We have drawn on the work of this Committee throughout our Report.

Policy Coordination

3.15. The themes which run through Spinks's principal recommendations are "coordination" and "coherence" in relation to the management of central Government's policy towards the subject: in the absence of the first the second is unattainable. Our feeling is that similar criticisms may be made with regard to other aspects of central science-policy decision making, of which, of course, national policy towards biotechnology is but one part.

3.16. The lack of coordination in governmental activities in relation to biotechnology noted by Spinks seems to be but a reflection of a greater lack of coordination in the management of science policy generally. Thus when your Committee took evidence from the then Minister of State at the Department of Industry and the then Parliamentary Under-Secretary of State at the Department of Education we were told that "Most certainly there is a science policy,"[3] but that its direction is fragmented within Government. Our attempts to discover how policy is made and coordinated elicited little evidence,[4] and in particular the role of the Prime Minister as the head of the policy making pyramid remained unclear.[5] The evidence we later took from the ABRC and from the Chief Scientist of the Central Policy Review Staff (CPRS) helped to confirm our feelings.[6]

3.17. The overriding impression we derived was of a loosely coordinated structure which may indeed serve well enough for the exchange and sharing of departmental views, but which, at the same time, appears to lack any sense of strong,

[1]HC Debates, 13 December 1978, Cols. 251–2W.
[2]See Annex 3.
[3]*Science Policy. Minutes of Evidence.* Wednesday 25 March 1981. HC 254–i, Session 1980–81, Q. 3.
[4]*Ibid.* Qs. 43–63.
[5]*Ibid.* Qs. 65–69 and 71–72.
[6]*Science Policy. Minutes of Evidence.* Monday 15 February 1982. HC 58–ii, Session 1981–82.

central guidance. The Royal Society has no formal connection with government. We reproduce the terms of reference of ACARD and the ABRC below.[1]

3.18. Our own views on the nature and efficacy of our central science-policy making machinery are borne out by the findings of the House of Lords Select Committee on Science and Technology in their inquiry into science and government. While conceding that there is no one way in which these matters should be handled, they found clear defects in the arrangements that existed in late 1981:

> "The Committee are convinced that the UK suffers from the lack of a body overseeing the whole of scientific endeavour, not least the relevance of S & T to Government policies, provoking strategic thinking, and encouraging conditions in which research of quality can flourish and results can get assimilated and exploited. At present there is a vacuum at the centre, which, for example leaves the work of the Research Councils and universities and the scientific advice they can provide ineffectively linked with either Departmental policies or with the scientific and technological needs of industry and its contribution to research."[2]

We have no reason to believe that the situation is any different now.

The response to Spinks

3.19. The Government's response to Spinks appeared a year later.[3] It was unenthusiastic both to Spinks's diagnosis and to his recommendations. Its reception by those most closely engaged in the subject reflected their disappointment. Thus *Biologist,* the journal of the Institute of Biology, may stand for others when it said that the White Paper "poured cold water" on professional expectations; it was "a masterpiece of bland platitudes" and "underlines the failure of Government to appreciate the importance of the subject". Linking its comments to a summary of the 2nd European Congress on Biotechnology, held at Eastbourne in April 1981, the journal reported that it was believed that there had been no consultation in the period between the publication of Spinks and of the White Paper.[4] When witnesses were asked for their views on the Government's response to Spinks they were uniformly dismissive.[5]

[1]ACARD: To advise Ministers and to publish reports as necessary on:
- (i) applied R and D in the United Kingdom and its deployment in both the public and private sectors in accordance with national needs;
- (ii) the articulation of this R and D with scientific research supported through the Department of Education and Science;
- (iii) the future development and application of technology;
- (iv) the role of the United Kingdom in international collaboration in the field of applied R and D.

ABRC:
- (i) To advise the Secretary of State for Education and Science on his responsibilities for civil science with particular reference to the Research Council system, its articulation with the universities and departments, the support of post-graduate students and the proper balance between international and national scientific activity;
- (ii) To advise the Secretary of State on the allocation of the Science Budget amongst the Research Councils and other bodies, taking into account funds paid to them by customer departments and the purpose to which such funds are devoted;
- (iii) To promote close liaison between Councils and the users of their research.

[2]First Report, HL 20–I, Session 1981–82, para IV 17.

[3]*Biotechnology.* Cmnd. 8177, March 1981.

[4]*Biologist,* June 1981, p. 123.

[5]Ev. p. 1; Q. 6.

3.20. The most careful reading of the White Paper does not reveal a single clear, unambiguous response to any of Spinks's 24 recommendations. Now, more than a year on from the publication of the White Paper there are signs of change. These were succinctly described by the Secretary of State for Industry.[1] We are glad to see these being implemented, albeit in some cases somewhat tardily. We note the setting up of an Interdepartmental Committee on Biotechnology.[2] We welcome the fact that this development has been stimulated by our decision to investigate the subject.

3.21. We have, so far, come across a number of problems which involve aspects of biotechnology. The general difficulty was pointed out by Sir Harold Hartley—that the UK position in this area has been allowed to slip.[3] This country is falling behind its competitors not just because of recent policy decisions or the lack of them, but because for too long too little attention has been given to the importance of a clear science policy for the UK. As we will see in the following pages, coordination and coherence of effort have a direct bearing on the protection of the research base.

Section 4: Coordination and Decision-Making

4.1. The main participants involved in the coordination of the biotechnology effort in this country are: the Department of Industry, with its Interdepartmental Committee on Biotechnology which was set up in April 1982 under the chairmanship of the Government Chemist, Dr Coleman; the Research Councils with their Inter-Research Council Coordinating Committee on Biotechnology (IRCCCOB) which was set up by the Heads of Research Councils (HORC) and to whom it has just made its first annual report; and the University Grants Committee (UGC) with its two sub-committees on Biology and Technology and its system of funding the universities in collaboration with the Research Councils, which is known as the dual support system.

4.2. In addition, Dr Coleman and Dr Potter, who is head of the SERC Biotechnology Directorate, are members of the Chemical Manufacture and Biotechnology Executive Committee of the Materials and Chemicals Requirement Board. But the lack of a formal link between the Department of Industry and the UGC is a serious weakness in the chain, bearing in mind the importance of the biotechnology research base. We make recommendations on this point in this paragraph and in paragraph 4.11 below. The Department of Industry has a view that it would wish to see "a greater share of the money, and therefore, the effort from the universities going on to scientific and technological subjects",[4] but has no formal machinery for expressing its view to the UGC and to the Secretary of State for Education and Science. Therefore **we recommend that some machinery be established by which the Department of Industry has a formal channel of communications with the UGG.**

[1] Q. 339.
[2] Department of Industry press notice no. 113, 19 April 1982, and Ev. p. 115, para. 11. See para. 4.1 below.
[3] Para. 3.12 above.
[4] Q. 354.

4.3. The Confederation of British Industry (CBI) in a constructive submission to the Committee, emphasising the contribution which biotechnology should make to the British economy, drew attention to the effect of the cuts on higher education and stated that "it is essential that centres of excellence clearly producing good fundamental research in biotechnology should be safeguarded from such cuts".[1] They regarded it as necessary that industry should be consulted on this in order to safeguard valuable research centres. This raises in an acute form the question of coordination. It is only the combined efforts of industry, government and the universities that can successfully combat the ills that assail the country's research base in biotechnology.

4.4. Before we examine the demands made on each of the three groups, it would be helpful to set down what Spinks said on the subject of a coordinated effort in the country in 1980. The report says (p. 8 para. 5):

> "The absence of an established industry clearly identified with new biotechnologies allows Government policy in one industrial sector to have adverse implications for biotechnology in others and diminishes the attraction of the subject to engineers. The result of such interactions is that biotechnology has not grown in the United Kingdom in the coherent fashion which we believe is merited by its potential. What is required at this stage is a policy of "technology-push" reflected in a firm commitment to strategic applied research. This will progressively produce potentially marketable products and processes and the policy should then be for a more "market-pull" approach. In the past the United Kingdom has not shown itself particularly adept at recognising when there is the need for this kind of switch in policy nor, when the need is seen, for making the necessary adjustments. We need, as a nation, much better communication between those who are primarily market oriented and those who are primarily science or technology oriented and nowhere is this more true than in biotechnology."

The Department of Industry

4.5. The Department of Industry, in its Secretary of State's own words, is the "lead" department in biotechnology.[2] The ways in which it is involved with biotechnological research and funding are described later. Our particular interest here is in its Inter-departmental Committee.[3] Represented on this Committee are the Departments of Industry, of Energy, of the Environment, and of Health and Social Security and the Ministry of Agriculture. Also represented are the BTG, the Centre for Applied Microbiology and Research (CAMR) of the Public Health Laboratory Service, and three of the Research Councils: the ARC, the MRC, and the SERC. However neither the controlling body of the Councils—the Advisory Board for the Research Councils—nor the body to which it reports, the Department of Education and Science, is represented, although Spinks (para. 4.9) had wanted to see the UGC on such a committee, and the Chairman of the SERC expressed a similar wish to us.[4]

[1] Appendix 8; para. 6.
[2] Qs. 342–44.
[3] Ev. p. 115, para 11. See above, paras. 3.20 and 4.1.
[4] Q. 225.

The Research Councils

4.6. Just as the Department of Industry has its Committee devoted to coordinating the effort in biotechnology, so too have the Research Councils: the Inter-Research Council Coordinating Committee on Biotechnology (IRCCCOB). It is designed to monitor, coordinate and rationalise the activities of the research councils; and in addition to this it attempts to identify areas where, as a result of inadequate coverage of recent discoveries, new work should be initiated.

4.7. Three of the Councils themselves (MRC, ARC, SERC) have extensive programmes in biotechnology. The Natural Environment Research Council (NERC) has a more restricted programme of less significance in the Committee's work. Their work, and in particular that of the Biotechnology Directorate of SERC, will be examined in more detail in Section 5.

4.8. It is the role of these Councils to fund and encourage biotechnological research in the universities and, in the case of two of them, in their own laboratories. This also involves liaison with industry and other bodies with industrial interests.

The University Grants Committee

4.9. The other side of the dual support system is provided by the University Grants Committee.[1] Although it is recognised that this country has had a strong university and polytechnic research base in biotechnology, exact quantifiable evidence on this is not available. The IRCCCOB report[2] lists some 24 centres of research (Section 2.5) with significant effort in biotechnology.

4.10. The importance of the UGC's position in the funding of biotechnology research needs to be reflected in its decision-making structure. The Committee is not satisfied that this is fully adequate to the purpose. The Chairman of the UGC is, of course, a member of the ABRC but research council involvement with UGC decision-making is informal and *ad hoc*. The two UGC Sub-Committees, Biological Sciences and Technology, are each chaired by UGC members but have no record of detailed cooperation in the past. They came together as a joint body with representatives of the research councils to discuss the disbursement of £900,000 to selected universities which had strong inter-disciplinary links between biology and chemical or process engineering. The funds available were described by Professor G Morris as "very much a thin topping up rather than a major new initiative"[3] and although a major purpose of the new allocations was to provide funds for new posts the Chairman of the UGC said no more than that he hoped "that at least quite a lot of these posts are going to be genuinely new".[4] Thus in some cases the funds might well be used to re-establish posts (and perhaps individuals) which universities had already identified for abolition or redundancy as a result of the overall reduction in university grants. In other words the new funds could do no more than restore what the shortfall in dual funding has taken away.

4.11. The UGC's position, because of the importance of fundamental research in biotechnology, is crucial. Section 5 describes in more detail the present crisis in the operation of the dual funding system. The university contribution to research

[1]See HC 289–vii, UGC memorandum and oral evidence.
[2]First Annual Report to the Heads of Research Councils (March 1982). Unpublished. Copies available from IRCCCOB.
[3]Q. 434.
[4]Q. 424.

in biotechnology is of very considerable industrial and commercial importance, and we believe that there should be much closer links in this field between the Department of Industry as the "lead" department and the UGC. The UGC, as well as the Research Councils, should have an appreciation of the Department's strategic thinking in biotechnology and should be able to take this into account when allocating earmarked funds for biotechnology research and post-graduate post-experience work. If the dual funding system is to work effectively the UGC needs to know of departments or research teams whose research falls particularly into areas of industrial interest to the Department of Industry and may need to seek additional funds to ensure that the UGC contribution to such work is adequately maintained. The Department of Industry needs an interface with the UGC to improve its own appreciation of the university picture and to discuss future research strategy. We believe that it is essential that a dialogue on such matters is opened up between the Department and the UGC and **we recommend that the UGC should be represented on the Inter-Departmental Committee.** The two UGC Sub-Committees both have very broad remits and contain members who could not be expected to have detailed knowledge of biotechnology or understanding of its potential. They represent, therefore, too broad an umbrella to take such specific decisions about which university should be supported in a field which may or may not span the subjects covered by the two Sub-Committees. **We recommend that bearing in mind its potential economic importance a more specific decision-making structure be established within the UGC for strategic decisions about biotechnology.**

4.12. We move finally to the basis on which decisions on funding and organisation are made by the UGC. Obviously it is constrained by the funds made available. The UGC method in respect of the earmarked funds for biotechnology was to invite universities to make submissions detailing how they would use the proffered funds available.[1] The danger is that universities may not be sufficiently clear sighted about their own priorities and may seek to use these new funds to plug gaps created by their own failure to support externally recognised centres of research. Thus the new earmarked funds could go indirectly to prop up subjects to which the UGC would not accord priority. The Committee are anxious that the funds allocated will be used to create new posts for new members of staff and that they are not used to offset savings made against previously established UGC priorities. The Committee therefore **recommend that the UGC monitor the expenditure of funds so granted on an annual basis for the three years for which they are to be earmarked for biotechnology to ensure that they continue to be used for the purpose intended.**

Proliferation of Committees

4.13 It is apparent that the belated appreciation of the industrial and commercial potential of biotechnology has led to the spawning of an extensive committee network. In addition to those already mentioned we have also come across the Biotechnology Committee of the SERC and the British Coordinating Committee for Biotechnology, which is a committee of the Society of Chemical Industry. We agree with Professor Burke who said, "We really need action on the ground rather than time on committees".[2] We think too many committees are growing up which either absorb the valuable research time of those active in the field or provide a

[1] Qs 412-20.
[2] Q. 269.

platform for people who have abandoned research for committee work. It is important that this system should be simplified and made more effective. **We recommend that the Department of Industry should review, in consultation with the DES and ABRC, the present spread of committees with a view to ensuring that strategic decisions in regard to research and development are effectively transmitted through the system and that scarce scientific manpower resources are not wasted.**

4.14. We believe that Spinks's conclusion that there is a lack of coordination and coherence in our policy making at national level is still valid. This was the view of the witnesses from the Royal Society.[1] The ARC and MRC witnesses felt that an adequate national policy was emerging satisfactorily, but it appeared that the ability of the Research Councils to coordinate their own programmes was uppermost in their minds.[2] The NERC thought that the Research Councils could not "formulate a programme of very limited objectives in the absence of complementary policies from Government and industry".[3] The Secretary of State for Industry stated his attitude to coherence and coordination in research and development in evidence to the Committee.[4] The White Paper made it clear that "the main responsibility for turning the concepts and discoveries of the underlying science into useful products and services that can be marketed at home and abroad rests with industry".[5]

4.15. The question follows: What would constitute the elements of a national policy for biotechnology? The objectives of any policy adopted should be to serve some of our society's needs, and to create wealth and employment. We recognise that not all of these objectives are those that industry would customarily set itself. The Spinks report included a list of priority research areas, such as monoclonal antibodies, waste treatment and fuel production (para. 2.15). But the memorandum from Prutec included a list[6] that is closer to what we have in mind:

- reduction of dependence on petroleum-based fuels and feedstocks;
- reduction of imports of chemicals and natural products not produced in the UK;
- reduction of energy consumption in certain energy intensive industries;
- improved medical and veterinary products and care;
- improved crop yield and new food products;
- maintenance of cleaner air and water supplies;
- avoidance of costly sewer reconstruction.

The company went on to state that these areas could be given quantitative values which could then lead to "a ranked list of projects worthy of support".

4.16. We detect no signs of this type of thinking in the Government's approach to biotechnology,[7] which seems to be characterised more by *ad hoc* devices than farsightedness, and we wonder whether the Interdepartmental Committee is

[1] Q. 14.
[2] Qs. 47–52.
[3] Ev. p. 81, para. 2.5.
[4] Q. 345.
[5] Cmnd. 8177, para. 3.
[6] Ev. p. 47.
[7] Q. 345.

properly constituted or sufficiently strong to devise and then carry through a coherent, coordinated national strategy. Spinks (p. 8, para. 6) states that:

> "We are not convinced that in our mixed economy the tasks posed by the problems we have identified can be met by the private sector alone. We believe that, in the interests of improving industrial competitiveness and paving the way for industrial innovation, a concerted approach is now needed from Government and industry to provide the coherent framework and mechanisms necessary for the successful development of biotechnology and of industries based on it."

Much of the evidence we have received shows a strong desire for a lead from Government.

4.17. We must bear in mind that the difficulties we have pointed out here relate to the first of our problems, the lack of a coordinated coherent science policy in this country. The Secretary of State for Industry told us that he had no doubt that he was the "lead" Minister for biotechnology.[1] **We recommend that the Government should make this explicit and that the Department of Industry, because of its financial stake in the successful exploitation of biotechnology, should be responsible for its overall promotion.** In making this recommendation we are conscious that very much more positive action is required on the part of the Department of Industry to improve its links with the University Grants Committee.

SECTION 5: THE UGC: DUAL SUPPORT SYSTEM

5.1. University research is funded through the dual support system. General university funds, made up of student fees and grants from the University Grants Committee, are supposed to provide for the basic research infrastructure, allowing academic staff to pursue a basic level of innovatory research. As areas of work develop promise, these are further supported by additional grants from external sources, particularly the Research Councils. External grants are meant to cover only the additional costs of a research project, and they rely on there being adequate background support through University funds. We received the Merrison Committee's report on the Support of University Scientific Research[2] late in our inquiry, and we refer to it in more detail later. It did however cover much of the ground in this section.

5.2. It is now accepted in universities, scientific societies and by the Chairman of the UGC[3] that the UGC support to universities is becoming increasingly inadequate, both for equipment and for recurrent expenditure. The run-down of major equipment imposes a serious problem, not least in creating a severe drain on recurrent resources because of the inevitable increase in associated maintenance costs. The inadequacy of the recurrent funding no longer allows a signficant level of exploratory activity, making serious research completely dependent on external funding. A major impact of this aspect is the collapse of the dual support system.[4] The financial pressure within the system as a whole is so severe that institutions are unable to replace staff. There has been little protection for biotechnologically orientated departments, and even groups with international reputations in the area are suffering severely. This problem is equally apparent at academic and technical levels, and represents a dire threat to the maintenance of an internationally com-

[1] Qs 342-44.
[2] Cmnd. 8567, HMSO, June 1982.
[3] Qs. 451, 458.
[4] See e.g. Qs. 14; 233–235; 283; Ev. p. 91.

petitive position in the future. There is difficulty in supporting the recurrent expenditure of Ph.D. students, whose laboratory costs are not provided from other sources. (The Research Councils provide a small contribution in the form of the Research Training Support Grant.)

5.3. The Committee have received a very critical response from the university community about the funding situation. Twelve university departments involved in biotechnological research responded to an invitation to send written evidence to the Committee and each one stressed not just the effect of the recent cuts imposed in the UGC letters of 1 July, 1981[1] but also the long-term damage that has been done to the research base by the reduction in university income over a period of years. The University of Birmingham told us "that funding by the UGC to support the research base in universities has never been adequate and is being further eroded at an alarming rate".[2] The University of Bristol said the UGC funds supported no more than two or three weeks worth of research in a full year.[3] The Royal Society, the Biochemical Society and the Society for General Microbiology, the major scientific societies in the field, were unanimous about the need first and foremost to protect the research base relevant to biotechnology. The point made by all three societies is that biotechnology is an "ideas led" discipline[4] and that one cannot predict accurately where new developments will take place or in what direction they will point. There was little support among the universities for a narrow "centres of excellence" approach to funding because good work which might later become significant for the whole field may be carried out at many universities. One indication of the effect of a reduction of research support may be that between 1967 and 1971 about 30 per cent of biotechnology patents world wide were issued to the UK holders while between 1977 and 1981 the figure had fallen to less than 1 per cent.[5]

5.4. Conditions have considerably worsened since 1 July, 1981. Biochemistry is a key discipline for biotechnology, has been starved of funds for some years, and now appears to be losing 12 per cent of academic and support staff. The Royal Society told us:

> "The problem in universities is a serious one. Fast growing areas suffer disproportionately when there are recruitment restrictions, and there are now strong pressures against refilling vacant posts when biotechnologists leave universities for industry, leave alone creating the necessary new posts to support an expanding demand for trained manpower. These pressures extend even to groups which would invite substantial industrial funds into universities. In turn, lack of career prospects and support staff encourages the best of younger scientists (say 28 to 38 year olds) to accept alternative employment, largely overseas, and with their posts then frozen the vicious circle is completed. It is desirable that scientists should be able to move from universities to industry (and *vice versa*) and that graduates take up employment in industry,

[1]These were the separate letters sent by the chairman of the UGC to individual universities with his circular letter of general guidance of the same date.

[2]BQ 12: a2. (BQ. refers to the individual answers to the questionnaire the Committee sent out; these have not been printed, but an analysis of the answers is in Annex 1. See note 2 on p. iii above.)

[3]BQ. 3: a6.

[4]Qs. 289–292.

[5]Dr A Colman "Current Status of Biotechnology in the U.K." in *Genetic Engineering: Commercial Opportunities in Australia*, p. 22.

but not if this results in inadequate training capabilities in universities and polytechnics."[1]

5.5. Professor Perry, Head of the Biochemistry Department of the University of Birmingham said that as a result of the cuts he was required to lose six members of staff out of 33. "If the system works, the less efficient will go. The innovators, the good men are stressed already. They are the men who can produce the ideas; and they are going to be working even harder; so that you are in effect eroding the research base in a very positive way by these cuts".[2]

5.6. There was general agreement that the UK is missing very important opportunities in the field. Many witnesses felt that time had been wasted since the publication of the Spinks Report: able staff were either going into non-scientific professions, because there were few career opportunities for permanent academic posts, or were going abroad—some of the best British academics were being recruited by overseas competitors. Dr Nicholson, Chief Scientist, Central Policy Review Staff, told us that he had been alarmed as a member of the Board of Biogen at the number of able British scientists applying for posts in Biogen's laboratories in Geneva.[3] The loss of morale was clearly evident, in particular to industry. Dr James of Unilever said that the expenditure cuts were inhibiting risk taking in university research and were depressing the number of imaginative grant applications being submitted to SERC.[4] Dr Walker of TDC said that the universities "feel under threat, they are operating on marginal economics, they are selling their technology wherever they can in the short term, they are not being enabled to take a longer-term view".[5] Dr Allam of Prutec believed the cuts were having "a severe effect".[6] This view was shared by the Medical Research Council. Dr Vickers said "I am sure the cuts are biting, there is no doubt at all about that . . ." "It is quite clear" he continued "that there is a very serious blow to morale as a result of the present situation".[7]

5.7. The main problem seems to be that as the Glaxo Group Research Ltd told us "the UGC grant is no longer providing the well-found laboratory upon which research council grants have been based".[8] The MRC was so concerned about this that Dr Vickers indicated that in consultation with the UGC the MRC "will selectively bend or yield certain of the principles of a dual support system"[9] in order to protect research teams where the research ability of a team is out of proportion to the scale of UGC support. In its evidence MRC stated that "The most important single factor in the protection of Britain's centres of excellence in the universities is the return to reality of the dual support system".[10] The ARC also indicated that it is giving support for departmental costs which previously it saw as the UGC's responsibility. Sir Arnold Burgen, Vice-President of the Royal Society, thought that the UGC side of the dual funding system had "totally failed".[11]

[1]Ev. p. 1.
[2]Q. 286.
[3]*Science Policy. Minutes of Evidence*, Monday 15 February 1982. HC 58-ii, 1981-82, Q. 177.
[4]Q. 243.
[5]Q. 155.
[6]Q. 174.
[7]Qs. 82, 83.
[8]Appendix 12, p. 37.
[9]Q. 75.
[10]Ev. p. 21, para 5.
[11]Q. 14.

This comment was made before the UGC announced its earmarked funds for biotechnology, but the Committee believe that the evidence we have received amply supports the view of the *Report of a Joint Working Party on the Support of University Scientific Research*[1] which states not only that the dual funding system has been under strain for some years because of economies required in the 1970s but that the more recent cuts may have a "potentially disastrous effect" on the prospects for university research. The Joint Working Party concludes "that there will be damage and that it will be substantial".

5.8. There have been two phases of financial cuts wreaking damage on the research base. In the first the damage has been on a long-term scale in which universities have been starved of funds for years, eroding the research base.

5.9. The second phase is expressed in the recent cuts in funding imposed on an already weakened base, which have intensified the problems arising from the long-term reductions. As a result of this, witnesses now claim that the dual support system has collapsed.[2]

5.10. Biotechnology is particularly vulnerable in the present situation because of its multidisciplinary character. Biotechnological research can be found in departments of biochemistry, biology, botany, chemistry, chemical engineering, control engineering, environmental science, genetics, microbiology and in faculties of agriculture, medicine and veterinary science. Even if a university administers the cuts selectively it is difficult to protect a subject which is spread over so many disciplines and it is clear that in some universities even-handed cuts are being applied under which all disciplines suffer. The same problem existed for the UGC in seeking protection for biotechnology in its 1 July 1981 letter. Except in the case of the SERC, where the Biotechnology Directorate exists precisely to deal with this problem, there is also a difficulty in the Research Councils because applications for support in biotechnology sometimes fall uneasily between the remits of different research grant awarding committees.

5.11. It is because of the breadth of the subject that neither IRCCCOB (para. 2.5.)[3] nor many of our witnesses support the Spinks Report's recommendation (para. 4.15.) that "a limited number of centres of excellence in biotechnology should be built up in universities". We agree with IRCCCOB's view that such a policy would be difficult to implement and we support its suggested alternative approach of developing "specific areas of expertise at particular universities to fill gaps where major potential exists". We also support the UGC's initiative to make earmarked grants selectively to universities where research can be effectively developed in biotechnology.

5.12. It has become abundantly clear to the Committee that a selective policy can only be effective if support at an appropriate level is available through the UGC for Science and Technology as a whole. We strongly agree with the Merrison Report that "the support of university research . . . is a matter of vital national interest . . . (and) that in facing the challenges of the years ahead the nation will rest heavily on the highly qualified scientific and technical manpower produced by the universities and on the vigour and vitality with which universities pursue their

[1]ABRC and UGC, Cmnd. 8576. HMSO, June 1982, the "Merrison Report".
[2]See para. 5.2 above, footnote 4.
[3]See para. 4.9, note 2, above.

research and stimulate innovation".[1] **We therefore recommend that priority should be given to the restoration of support for scientific and technological research within the dual funding system. We also recommend that further earmarked support should be given for research biotechnology both through the UGC and the Research Council mechanism.** We have already recommended that there should be much closer links between the Department of Industry and the UGC,[2] and we believe that this could be used to facilitate the creation of a more coherent policy for the support of scientific and technological research in this country.

The Research Councils

5.13. Whilst all the Research Councils fund research, their systems operate in slightly different ways. The SERC operates exclusively through the universities and polytechnics, while the MRC also funds research in its own research institutes. The ARC's system we have already referred to. The Councils in their different ways have recognised the potential of biotechnology and made considerable efforts to support activity in this area.

The Science and Engineering Research Council

5.14. The Science and Engineering Research Council has established a Biotechnology Directorate, with a senior full-time director having responsibility for stimulating and coordinating national effort in biotechnology. The director and his management committee, made up of both academics and industrialists, take an active role in identifying areas of biotechnology that require increased attention and in persuading universities and industry to interact in bringing ideas to fruition in commercial development. The Directorate's interests span a wide area of biotechnology, including not only biology but also engineering aspects, downstream processing and process control. The Directorate has its own funds available for financing research projects and taking necessary initiatives. The SERC currently spends £1 million annually on biotechnology research, but expects to increase this to about £2.5 million by 1985–86. The Council also fosters interaction between the universities and industry through its Cooperative Awards in Science and Engineering ("CASE") scheme for post-graduate training and the Cooperative Grants Scheme.

The Medical Research Council

5.15. The Medical Research Council is largely concerned with the application of biotechnology in medicine, though wider industrial applications are occasionally pursued. MRC-funded groups have been prominent in the development of two major areas of current interest, genetic engineering and monoclonal antibodies. The Council's involvement in the area ranges from basic underpinning research, on which £17 million was spent in 1980–81, to more directly biotechnological projects, on which £1.7 million was spent in the same year.

5.16. The Council funds work both through grants to universities and through financing its own establishments. It also promotes activity in the area through special schemes such as research studentships and postdoctoral fellowships for training in recombinant DNA techniques.

[1] *Op. cit.*, p. 1, para. 3.
[2] See para. 4.2 above.

5.17. The MRC has expressed concern over the adequacy of the UGC funding of the research base in universities, and is attempting to minimise the impact of the UGC cuts in selected areas by making contingency funds available.[1] It is also aware of the difficulties of funding the recurrent expenses of Ph.D. trainees in modern biology, and attempts to alleviate this situation by relatively generous provision of research expenses on project grants.

5.18. The Research Councils' relations with Celltech are described in Section 6.

The Agricultural Research Council

5.19. The Agricultural Research Council has the primary aims of organising and developing agriculture and food research throughout the United Kingdom. It operates largely through its own research institutions, but also supports relevant research in the universities and polytechnics. The Council's expenditure for research in 1982–83 is expected to be £92 million. The ARC identified genetic manipulation as a priority area in 1977 and initiated a coordinated programme in that area. The programme includes work on the production of vaccines for protection of animal health, the genetic manipulation of plants and animals and the utilisation of animal waste for methane-production. More recent initiatives have led to programmes on monoclonal antibodies, immobilised cell systems for ammonia-production and the production of high value flavour compounds. The Council also supports major programmes on micropropagation of plants, biological control of disease, photosynthesis and vaccine-production. The annual expenditure on all aspects of biotechnological research is about £4.8 million.

5.20. The ARC states in its submission to the Committee that its programme is "being developed with a keen awareness of the commercial potential of some of the work. Companies have been involved wherever possible, on terms compatible with the Council's obligation to involve BTG in the development and exploitation of know-how and innovations".[2]

5.21. The ARC emphasises that in developing an effective programme of research in biotechnology "the degree of central planning and coordination is crucial. If there is too little the programme may lose its coherence and the scientists their common sense of purpose; too much and the innovative skills and drive of the research leaders may be stultified".[3]

5.22. The Research Councils are the bodies, after the university departments themselves, most adversely affected by the collapse of the dual support system. The SERC and the MRC both expressed deep concern over the effects financial stringency is having on research work. Even the ARC felt the effects, though most of its funding goes to its own institutions and has developed a very strong programme. To quote Dr Vickers of the MRC "there have been occasions where the research councils collectively have averted a disaster".[4] Dr Ingle of the ARC expressed his concern in his comment "there may not be the adequate openings for these young scientists here. Therefore, I do not think it is a question of having to top up what they get, but simply a question of having the jobs for them".[5] And finally, in

[1]Qs. 74–80.
[2]Ev. p. 18, para. 16.
[3]*Ibid.*, p. 19, para. 17.
[4]Q. 90.
[5]Q. 125.

reply to the query "Are you satisfied that there is a sufficient number of academic staff at this present time to provide the training envisaged?", Professor Kingman, the Chairman of the SERC replied "No, there is not".[1] The Committee strongly support the suggestion that a solution would be provided by the UGC earmarking money for specific areas of biotechnology.[2] **We recommend that the practice of the Research Councils in earmarking a proportion of their funds for biotechnology be rapidly improved in future years.**

Section 6: Department of Industry and Other Government Investment in the Research Base

Department of Industry

6.1. It is now recognised in most of the advanced industrial nations that biotechnology is an important area for government investment. The Japanese Ministry of International Trade and Industry is supervising a \$110 million (£64 million) 10 year grant to 14 companies led by Mitsubishi Chemical Industries Ltd., for the long-term promotion of biotechnology.[3] The West German Government is increasing spending on biotechnology research through the Federal Ministry of Research and Technology from \$22.7 million (£13.2 million) to \$29 million (£16.9 million) p.a. The French Government has selected biotechnology as a priority area for R and D expenditure and is offering to defray 50 per cent of universities. It has been estimated that the French Government is spending Fr 1,100 million (£91.7 million) on biotechnology a year. The Dutch Government has recently announced a \$29.4 million (£17.1 million) programme in biotechnology applied to agriculture and dairy products. Canada has established a \$100 million (£58 million) fund over 10 years to prosecute research and development in biotechnology. In the USA the Federal Government is spending about £55 million in 1981 through the National Institutes of Health on biotechnology and renewable energy.

6.2. Against this our own Department of Industry estimates it has given financial assistance of £15 million over a period to industry for biotechnology and has established a £2.5 million annual fund for industrial research.[4] The Department of Industry, in its submission to the Committee, and in a subsequent letter from the Secretary of State for Industry,[5] described the Department's involvement in research through its own research requirements boards, laboratories and services.

6.3. The Department of Industry has a close liaison with the SERC's Biotechnology Directorate: as the Research Council states in its submission to the Committee "wherever possible the SERC wishes the research it supports in biotechnology to be relevant to the needs of British industry, and to be carried out in collaboration with industry".[6] Later in the paper it adds "the Directorate provides some services for the Department of Industry's programme and thus has an overview of the support of biotechnology from basic research in universities and

[1] Q. 250.
[2] *Ibid.*
[3] Appendix 15, p. 47, M D Rogers: "The Role of the Japanese Government in Biotechnology Research and Development".
[4] Q. 339.
[5] Ev. pp. 114–5; pp. 132–4.
[6] Ev. p. 64, para 9.

polytechnics through to the Department of Industry programmes supported in industry and Government laboratories".[1] The Department confirms that it "works closely with the SERC's Biotechnology Directorate to bring together university research and industrial development and application".[2]

British Technology Group

6.4. The Department of Industry describes itself as having "sponsorship responsibility for the BTG".[3] The Group is the result of a merger in 1981 between the National Enterprise Board (NEB) and the National Research Development Corporation (NRDC). As the Group's memorandum points out, one of the main objectives of this closer collaboration of the two bodies "was to facilitate the 'pull through' of new technology from the laboratory to the market place".[4]

6.5. The Department of Industry's memorandum[5] spells out the complementary roles of the two bodies within BTG—NEB is intended to have a catalytic role in the development of new technology; NRDC is concerned with the commercial exploitation of inventions or developments resulting mainly from publicly-funded research and with provision of risk finance for innovation. The BTG's memo[6] sets out the range of services and roles the Group provides, and states that its "current commitment to biotechnology is some £13 million which has acted as a catalyst for a substantial amount of private sector investment". The BTG plans to invest more than this again in the next 2 or 3 years.

6.6. Though it is perhaps too soon after the formation of the BTG for us to judge its success in bringing the two sets of functions and operations together to achieve the "pull through" of new technology referred to above, nevertheless the weight of evidence we have received was very critical of the NRDC in its former role before the merger.[7]

6.7. The issues of investment and exclusivity to the rights to inventions coming from publicly-funded research are the essence of the problem which we now outline.

6.8. Only too frequently we have encountered evidence suggesting that the monopolistic powers of the BTG (NRDC) over patents and royalties deriving from research funded through research committees should be terminated.[8] The Leicester group of companies[9] confessed that an earlier attempt to form an industrial/university research laboratory had foundered on the NRDC's demands concerning royalties on patents. We received a good deal of criticism to the effect that useful inventions rejected by the NRDC had been taken up elsewhere, that letters had gone unanswered, and that the NRDC had not been popular with industry.[10] It has not been possible to investigate the justice of these complaints but we feel they

[1] *Ibid.* para. 17.
[2] Ev. p. 115, para. 10.
[3] British Technology Group. Ev. p. 114, para. 2.
[4] Ev. p. 41.
[5] Ev. p. 115, para. 9.
[6] Ev. p. 41.
[7] Qs. 26, 27, 188, 332; BQ. 11: a 12.
[8] BQ. 5, BQ. 13: a 12.
[9] See para. 7.3, below.
[10] Qs. 186, 188.

are symptomatic of the relations which have been developed with the NRDC. We agree with Dr Walker of TDC when he told us:

> "the dimensions of investment the UK makes in its universities do not make it appropriate to give a state body total monopoly rights to patentable inventions because of the onerous task that is placed upon them (BTG) to execute that and be seen to be fair to everyone involved . . . we should have a system whereby people who are patenting inventions—the owners of the inventions with the universities and the universities themselves—should feel a responsibility and want to identify themselves with clear commercial success, and that is the case with a lot of them who do not get their letters answered, where developments may not be commercial. If you do not answer, if you have not got an organisation that can reach these people, they will never think about invention and I think this general air of disillusion that you see in large parts of British universities has got to be overcome."[1]

6.9. The Committee were pleased to hear from the Secretary of State for Industry that the BTG monopoly was "long overdue for examination" and that he intended to take a decision on the matter "quite quickly".[2] **We recommend that the BTG's monopoly rights over research funded by the research councils be removed and that, while it should have the right to be informed of all patentable inventions, the restriction on scientists taking their research to the open market be abolished.**

Celltech Ltd

6.10. The creation of Celltech Ltd. in 1980 must be accounted the most important recent initiative. It was established as a vehicle for the commercialisation of genetic engineering and hybridoma technology. The company, based at Slough, was formed with a share capital of £12 million by a group of shareholders including the National Enterprise Board, Technical Development Capital, Prudential Assurance, the Midland Bank and British and Commonwealth Shipping Co.[3]

6.11. The formation of this company represented a positive response to the Spinks Report (para. 4.14.). But whilst Celltech has been described by one commentator as "probably the jewel in the British biotechnological crown"[4] it was not brought to birth easily. MRC witnesses were not willing to talk freely about this, but it was apparent to us that a great deal of obstructiveness was demonstrated along the way.[5] Not all of our witnesses were convinced that it was an entirely necessary or desirable conception.

6.12. Dr Copsey, of Prutec, drew attention to its privileged position:[6]

> "I would say if Celltech had been a company like the other venture companies that had to go out and create opportunities for itself, develop relationships, draw up contracts with individual universities and it was unable to do so, then everything that David Beattie [Head of the Biotechnology Investment Division, BTG] has said would be fair—that it should really be up to Celltech to decide whether to transfer technology if it was not going immediately to

[1] Q. 186.
[2] Q. 367.
[3] See Annex 4.
[4] Laing & Cruickshank, *op. cit.* p. 49.
[5] HC 58–i (1981–82), Qs. 45–51 and 95–102.
[6] Q. 194.

develop and make use of it itself. I am sure Celltech has every intention of doing this with the less urgent products that they have. However, Celltech has been put in a monopoly position in respect of certain MRC funded laboratories where work of very great value—certainly I think most of our eggs in that particular basket—has been placed with Celltech. Therefore Celltech is not analogous to a private biotechnology venture company and must have responsibilities commensurate with its privileged position, and the same could be true of any other umbrella organisation."

In addition the Society for General Microbiology[1] doubted whether there should be another such company until Celltech's success was assured; the Society felt that it acted as a deterrent to risk taking by industry.

6.13. Under an agreement with the MRC, Celltech has rights to commercialise discoveries made by the Research Council. The MRC were able to give the Committee some of the details of this five year collaborative arrangement.[2]

6.14. Dr Vickers explained that "There is an arrangement whereby up to a limit royalties come to what is called the Celltech fund which is effectively money for the MRC to spend on projects, not necessarily in biotechnology, without hindrance"[3] indicating one of the positive benefits to MRC. However, in the light of the doubts expressed by other witnesses, the Committee do not feel they can unreservedly welcome the attempts by the ARC to collaborate in the creation of an agricultural analogue to Celltech.[4] We are opposed to exclusively in patent rights operated by any Research Council. **We therefore recommend that the Government should urgently review the relationship between the MRC and Celltech, particularly as far as exclusivity in access to MRC funded research is concerned, before the ARC proceed any further in their negotiations.**

Centre for Applied Microbiology and Research

6.15. The former Microbiological Research Establishment (MRE) at Porton Down, now the Centre for Applied Microbiology and Research (CAMR) deserves particular attention. It comes under the auspices of the DHSS, and yet as the Royal Society pointed out, has great potential for "developing new biotechnology programmes in concert with private industry".[5] Spinks felt (para. 2.6.) that the MRE's translation to the Public Health Laboratory Service[6] was a cause for concern since "it appears to us to have put its contribution at risk". The White Paper on Biotechnology said that the facilities and expertise of CAMR should, so far as is practicable, be available to help industry.[7] The valuable memorandum from the Public Health Laboratory Service Board[8] makes it clear that CAMR sees its own role very much in this light. CAMR's main effort is in the health care field, although it is not limited exclusively to this. **We recommend that an immediate study should be undertaken of the means by which CAMR's facilities and expertise may be utilised more effectively, and that its role as an adjunct to university research should be explored.**

[1]Ev. p. 94.
[2]Qs. 95–102.
[3]Q. 95.
[4]Qs. 105–110.
[5]Appendix 9, para. 18.
[6]DHSS Press Notice, February 1978.
[7]Cmnd. 8177, paras. 25, 27.
[8]Appendix 13.

SECTION 7: INDUSTRY'S INVOLVEMENT AND THE RESEARCH BASE

Industry-University Relations

7.1. The Department of Industry takes the view that "The successful industrial development of biotechnology in the UK will depend mainly on the efforts of private industry to invest and undertake research. The main sources of funds will be the profits of companies and capital provided by private financial institutions".[1] Because of the long lead time it expects that investment will mainly take the form of common stock seeking long-term capital growth. Dr Walker illustrated this from the application of biotechnology to agriculture. He said, "The complexities of invention necessary to make breakthroughs in this area require that investment in research, development and application are continuous over a 10 or 20 year period".[2] Unfortunately a good deal of evidence was put to the Committee that although there were a number of UK companies expert in the field, UK industry as a whole does not appreciate the overall potential of biotechnology. Moreover, perhaps because of the number of biotechnologists attracted abroad there is according to Prutec Ltd., "a shortage of well presented ideas which are capable of commercial exploitation and offer the relatively high rates of return on capital".[3] It is clearly vital to encourage industry to invest in research and development in biotechnology. Both the Royal Society and Technical Development Capital believed that tax allowances against capital expenditure for new projects would encourage investment in research.[4] **We recommend that the Department of Industry undertake a study on tax incentives for research.**

7.2. The future success in the development of biotechnology depends very much on the ability of industry to draw effectively on university research. Dr Walker of TDC summarised the problem as follows:

> "The fundamental research within universities is of a high standard bui the universities don't have sufficient understanding or real perception of market opportunities to present invention in the right form to make it attractive to industry. On the other hand I do not believe that industry focuses clearly enough on the real opportunities arising in universities."[5]

7.3. It is therefore of great importance to bring industry closer to the universities so that it can participate in the invention stage. A good example of how this can work in practice is the joint laboratory with ICI funded at the University of Leicester, and the further proposal there that four companies, John Brown Engineers and Constructors Ltd., Dalgety-Spillers Ltd., Gallaher Ltd. and Whitbread and and Co. PLC, should jointly fund a programme of pure and applied research at the University. The four companies submitted evidence to the Committee that "public funds should be the catalyst for cooperation between the universities and industry and they should be more readily available". The SERC have been particularly active in promoting schemes such as the Cooperative Awards in Science and Engineering (CASE) and the Cooperative Research Grant Scheme. Although we intend to refer to these in greater detail in Section 8, we think it appropriate to include them in our recommendations here.

[1]Ev. p. 115, para. 12.
[2]Ev. p. 48, Answer 5.
[3]Ev. p. 47.
[4]Ev. p. 173, para. 17; Ev. p. 49, Q. 10.
[5]Ev. p. 49, Answer 9.

7.4. We support this type of cooperation **and recommend an increase in CASE and collaborative awards, the establishment of teaching companies,[1] the provision of funds for post-experience courses, and long-term capital grants for buildings. We also recommend that the Department of Industry and other bodies should take every step necessary to improve the links between industry and the universities.**

7.5. Several witnesses commented on industry's slowness to invest in a field in which US and other companies have for some years been investing heavily.

7.6. The companies in the UK which are continually being given as examples of investors, such as ICI, Rank Hovis McDougall, and Glaxo seem to the Committee to be exceptions, not the rule. It is only comparatively recently that reports have started to circulate as guides to city investors on the investment possibilities of biotechnology. An example of this is the report, already referred to, drawn up by Jonathan Allum on behalf of the stock-broking firm Laing and Cruickshank. The conclusions he reaches, and the recommendations he makes, are positive and encouraging: "We are convinced that recent advances in biotechnology constitute industrial developments of the utmost importance in which the investor can participate".[2] But the report only appeared in March 1982. Investors in America had reached this conclusion some years previously.

7.7. The facilities provided by, for instance, the SERC Biotechnology Directorate are specifically aimed at bringing together researchers in academic institutions and representatives of finance and commerce. In addition the Engineering Technology and Industries Committee of the Royal Society is organising meetings increasingly concerned with industrial topics. The Royal Society have set up a fellowship in biotechnology "and will shortly have some rather more junior ones". It has also set up joint schemes with the SERC for moving people from universities to industry and vice versa.[3] **We recommend that methods be investigated of founding a series of up to a dozen of these fellowships so that those concerned in biotechnology in industry can have the opportunity of regular contact with appropriate universities.**

Other Areas of Concern

Awareness

7.8. Academics may not know what industry wants and cannot direct their work or interests accordingly. Industrialists may either have no clear idea what research is going on in universities, or do not fully understand its implications. Many cannot see any immediate benefit to industry, and do not fund the research. A better working relationship between the two can develop and where it exists has resulted in a flow of funds into supporting the research base; ignorance dams up this source.

7.9. Dr Allam of Prutec Ltd. explained to the Committee "it is difficult for people in universities and particularly for people with very pure academic backgrounds to really identify the product opportunities which are going to exist in the market without some kind of dialogue towards which they are aiming with industry . . ."[4]

[1]Ev. p. 64, para. 10.
[2]*Op. cit.* p. 1.
[3]Q. 32.
[4]Q. 168.

7.10. On the other hand we found evidence of a growing interest among scientists in the commercial possibilities of research. Dr Cain of the BTG said that there were "some very eminent scientists" who wanted "to be very intimately involved in their (inventions) commercial development".[1]

7.11. A solution to this problem lies in improving the relations between academics and industry, between those who discover and those who exploit. The work of the SERC's Biotechnology Directorate in this area is examined in Section 8 of this report, and its role in helping both sides can hardly be under-estimated. As Professor Kingman, Chairman of SERC, explained: "without someone taking an active entrepreneurial view there is a danger that the universities and industries together will not come fully to realise the potential that there is in their skill, time and ideas".[2]

7.12. We reiterate our strong support of the role of the Directorate in improving the relations, and forwarding schemes of cooperative work between the two sides, and can only hope that this positive approach will be adopted by other organisations.

Threat to Pure Research

7.13. There is a strong and understandable feeling that a too vigorous pursuit of commercial success could have a damaging effect on the strength of the fundamental research which must provide the intellectual basis from which applied research and subsequent developments eventually stem.[3] As Dr Vickers explained, it is the MRC's managerial problem "to make sure that one does not prejudice the spirit of research, which is essentially an unstructured thing at this very high level of innovation, by trying to impose on it commercial constraints".[4]

7.14. The problem seems to lie in the fact that biotechnology and industry are inextricably involved. Industry is being encouraged to fund research in universities. Industry however, is understandably reluctant to fund work with no apparent commercial application in sight, over a period of years and at some considerable cost. These are three significant deterrents to investment. Ideally industry wants a programme of research strongly weighted in favour of the applied side. Not surprisingly many academics are concerned lest this drive be at the expense of pure research. The MRC may take justifiable pride that its faith in the "unstructured" research into molecular biology that it is has supported for many years has now paid off so handsomely and confounded the scepticism of some eminent commentators on science policy issues.

7.15. We recognise that there will always be different views about the right balance in British universities between pure and applied research. Though we do not believe that the pendulum has yet swung far enough to endanger our high standing in pure research there is no reason for complacency.

Consultancies

7.16. We have received evidence on consultancies to the effect that they can be both beneficial and detrimental to the universities. Professor Hartley told us that it was an activity "hallowed by tradition".[5] Professor Lilly explained that

[1] Q. 184.
[2] Q. 212.
[3] Ev. p. 21, para. 2.
[4] Q. 103.
[5] Q. 34.

"in our department we are encouraged to consult because of the benefit to us and that benefit is that we are able to interact with companies and learn what would be useful for us to do in the way of research and also what would be good for us to teach",[1] thus drawing attention to a way in which industry's contacts with universities help to break in on the sometimes too confined world of the academic, stimulating his awareness and desire to work in different areas. A more obvious benefit was described, again by Professor Lilly, when he spoke of the fees earned by consultancy work. The work fell, he said, into two categories, one in which the scientist/consultant is paid, the other in which the university receives payment.[2] Either way future contacts and immediate financial benefits accrue from such a relationship. Nevertheless this is an area in which very large sums of money from both the USA and Japan are available to attract British academics. We feel that there should be greater clarity in universities about the proper balance of relationships of academics to industry and their institutions and the proper balance between the two. We wish to encourage the closest possible links between industry and the universities but we think this will best take place if it is clearer than it is at the moment to both how much time academics can properly devote to their industrial consultancies and the extent to which such consultancies and the associated contracts that go with them should inhibit academics from sharing freely with their colleagues and students the knowledge they gained in industry.

7.17. However, some alarm has been expressed in universities about the intrusion of commercial considerations into academic life. A number of senior academics, have, for example, exclusive research and consultancy agreements with foreign companies. This has caused difficulties in some institutions because of questions of conflict of interest. Dr Walker of TDC explained: "When you are investing in fundamental research you by and large try to tie up individuals with some broad-ranging deals because when you have not identified particular inventions you try to do the next best thing—get hold of the people who might make the invention".[3] As Dr Allam pointed out, a scientist's loyalties are divided three ways: to his students, to his research group and to his industrial partners. The important thing is to try to reach a compromise "whereby all three groups do not suffer".[4] This is clearly a potential problem area, **we therefore recommend that universities prepare clear guidelines about proper conduct in this area and publish a list of the consultancies held by their members of staff.**

Section 8: Education, Training and Manpower

8.1. We consider here the problem of determining at which stage in the educational spectrum it is most appropriate to introduce formal training in biotechnology. We have done this with an awareness of the different levels of training which will be required. In the consideration of training, one difficulty has been that feature of biotechnology already remarked on to the effect that it is not a subject in its own right, but an amalgam of certain facets of biology, chemistry and engineering.[5] Most witnesses have insisted that it would be inappropriate to define an academic discipline of biotechnology.[6]

[1] Q. 35.
[2] Q. 36.
[3] Q. 175.
[4] Q. 179.
[5] Q. 2; Appendix 13, para. 4.1.
[6] Appendix 8, para. 9.

8.2. No evidence has been presented to suggest that biotechnology should be taught in schools. It has been emphasised that the role of schools is to provide a sound basis in the physical and biological sciences,[1] drawing attention, where appropriate, to examples of biotechnology. For this schools will need a broad based science curriculum which we recommended in our Curriculum Report.[2] However we feel that modest revisions in certain areas of the school curriculum are called for. Dr Potter, the head of the SERC's Biotechnology Directorate, suggested as an example that "if one could insert into those (examination) syllabuses some more applied aspects of biology, perhaps then one could inculcate the awareness of the applications of biology" into the pupils.[3] **We recommend that the DES should consult with industry and the universities and report on the extent to which this would be possible.**

8.3. The Royal Society in their report *Biotechnology and Education* strongly recommended not only in-service training to help teachers overcome this problem, but also "schemes for fostering school-industry links, of which there are a number".[4] The report goes on to enumerate schemes run by the Department of Industry, the Confederation of British Industry (CBI), and the Science and Technology Regional Organisations (SATROs). The Report also points out that the schemes run for the benefit of the teachers were "of undoubted merit to both pupils and teachers alike in engendering an awareness and a modicum of familiarity with industry".[5] Dr Vickers explained that he "would like to see schoolchildren taken into Glaxo or ICI because the excitement would come across there",[6] and clearly their responsiveness to the industrial aspects of biotechnology is desirable.

8.4. Most witnesses have suggested that at the undergraduate level, teaching should remain very much as it is at the moment, with students taking degrees in one of the relevant biotechnological disciplines.[7] It has been suggested that in some areas, such as microbial physiology,[8] a strengthening of teaching should be considered. The majority of witnesses have emphasised that it is in the field of chemical engineering that there needs to be considerable expansion,[9] both in the number of teachers and of places available, and that serious efforts will have to be made to persuade graduate engineers to consider further training rather than immediate employment.[10]

8.5. It is clear that the main effort in teaching should come at the post-graduate level.[11] The initial part of such training must be directed to "filling the gaps". Graduates from the biological sciences will need to master the concepts and language of, chemistry and engineering, while graduates from the physical sciences will have to come to terms with the relevant areas of biology.[12] It has been stressed that only graduates of high quality will be able to cope with this additional conceptual load.[13]

[1] Qs. 247, 139, 462.
[2] Second Report, Session 1981-82, HC. 166-I, para. 4.16.
[3] Q. 247.
[4] November 1981, para. 44.
[5] *Ibid.*
[6] Q. 139.
[7] Q. 132.
[8] Ev. p. 89, para. 4.
[9] *Ibid.*
[10] Qs. 132, 216, 259.
[11] Qs. 246, 419, 452.
[12] Ev. p. 88, para. C.4; Appendix 7, para. 1 (i).
[13] Ev. p. 88, *loc. cit.*

8.6. Opinions vary as to the subsequent nature of post-graduate training. It can be organised in several ways, e.g. traditional PhD,[1] tailor-made courses leading to a Masters degree such as the projected MPhil degree at Cambridge,[2] or short intensive post-experience courses.[3] It is agreed, however, that whatever the mode of training a considerable element of practical work must be involved.[4] It has been pointed out by a number of witnesses that an essential ingredient of such training must be an awareness of industrial application.[5] The success of this post-graduate training will depend on the quality of the instructors and the availability of appropriate equipment and materials.[6]

8.7. We have mentioned several times the commendable efforts made by the SERC to promote an increase in collaboration between universities and industry. This is done through a number of schemes which "will be used when appropriate in biotechnology".[7] We draw attention here to one of those schemes—the Co-operative Awards in Science and Engineering (CASE). In their paper to the Committee, the SERC explain that the "awards support students being trained in the methods of research who work on a project jointly devised and supervised by an academic department and a cooperating body such as a British company". The SERC goes on to say that several hundred of the projects "have been approved across the entire range of subject areas". "They are available at university colleges and polytechnics throughout the UK with support from private firms, institutes, local authorities and public bodies."[8] The Committee strongly support the SERC's attempts to consolidate and improve the relations between industry and the universities in this way. We welcome efforts by the MRC to set up a similar scheme.

8.8. In the light of the problem of shortage of funds and remembering the importance of developing industrial/academic collaboration we once more draw attention to the initiatives of the SERC. For the last five years the Council has run the teaching company scheme, which is funded equally by the SERC and the Department of Industry. It has brought the expertise and technology in the universities to industry where "it can be put to rapid and effective use in improving firms' manufacturing performance".[9] The benefit to the universities has been that it provides high quality post-graduates with the opportunity of working with "senior industrial engineers and academic staff while introducing new production methods".[10] In addition the Council has introduced the Cooperative Research Grant Scheme, which is "designed to encourage cooperation between academics and manufacturers who wish to develop new products or processes requiring research which has an academic content beyond the resources of their own research and development departments".[11] The SERC considers "supporting the academic side of the collaboration, provided that the company makes a substantial contribution in effort, material and expertise. The SERC contribution may be up to

[1]Qs. 14, 313.
[2]Q. 379.
[3]Qs. 419, 453, 456.
[4]Ev. p. 88, para. C.2.
[5]Qs. 257, 379.
[6]Qs. 132, 135, 252, 257.
[7]Ev. p. 64, para. 10.
[8]Ev. p. 66, Annex A.
[9]SERC, *Annual Report 1980-81*. pp. 29–30.
[10]*Ibid.*
[11]Ev. p. 66, Annex B.

three times that of the company in terms of direct costs".[1] There are benefits to be gained by both sides from this sort of collaboration which the Research Council lists in its paper to the Committee.[2] We note with particular satisfaction its comment that "there is considerable interest in the use of the Cooperative Grants Scheme, and three grants of this type" (involving programmes in biotechnology) "have already been awarded".[3] We are greatly encouraged by the SERC's success in persuading industry to help to support research work.

8.9. The extent to which post-graduate training will develop depends on the estimated need for trained biotechnologists. The projected need for 1,000 biotechnologists over the next 10 years implies a minimum training quota of 100 per year.[4] It is reasonable to assume that some of those trained will go overseas after training.[5] If the courses established develop an international reputation, as might well be anticipated on the basis of the academic standing of the teachers, overseas students may be attracted to them. Such students will be welcomed by British Universities for financial as well as academic reasons. Thus we consider it not unreasonable to anticipate a requirement considerably beyond the Royal Society's minimum of 100 trainees per year. **We recommend that training quotas are arranged to meet this objective.**

8.10. The number of centres where such training is carried out must be carefully considered. It is unrealistic to assume that every university and polytechnic can provide courses.[6] Equally the provision must not be so restrictive as to prevent development of new courses in the future. The SERC has suggested about six well-designed courses, each of one year's duration, for which it would provide studentships—5 to 10 per course.[7] The UGC has identified a number of centres which it will support by way of earmarked grants, some of which would obviously provide advanced courses.[8] It is encouraging to see that among the twelve centres so far identified there is an attempt at grouping which should enable institutions to collaborate in teaching and research.[9] In all it might be reasonable to assume that twelve to fifteen institutions would be actively engaged in post-graduate training in biotechnology. It is however important to be aware that the university system is not static and that in the next decade changes may have to be made in the centres supported.[10] As pointed out by the Society for General Microbiology, centres of excellence depend as much upon people as upon facilities.[11]

8.11. It would be unrealistic to assume that this training can be given by existing university and polytechnic personnel.[12] As we have seen, because of public spending cuts, universities are having to face a serious depletion of resources.[13] The generally used tactic of leaving posts vacant has led to a random reduction of staff and a serious undermanning in certain departments, both of which have extremely harm-

[1] *Ibid.*
[2] *Ibid.* pp. 64–5.
[3] *Ibid.* p. 64, para. 10.
[4] Ev. p. 65, para. 12.
[5] Ev. p. 21, para. 3.
[6] Q. 218.
[7] Ev. p. 65, para. 13.
[8] Ev. p. 137, paras. 10–11.
[9] BQ. 8: a 2.
[10] Q. 291.
[11] Q. 289.
[12] Appendix 3, para. 2.
[13] Appendix 4, para. 5.

ful effects in a multidisciplinary subject such as biotechnology. This is exemplified by the situation obtaining in the Department of Chemical Engineering at Cambridge University.[1] Introduction of new courses is expensive in terms of teaching staff, equipment, library facilities and basic research provision.

8.12. Thus if biotechnology is to expand and become an established part of British tertiary education the problem of funding and the collapse[2] of the dual support system must be faced. This was accepted by the Research Councils who were looking at novel ways of funding research in institutions without the necessity of providing a well found laboratory.[3] Therefore all possible sources of funds must be considered for the establishment of the courses described.[4] **We recommend that adequate provision be made as soon as possible for the establishment of new training courses, and that their progress be monitored by the Department of Industry.**

8.13. The UGC must continue to play a central role in the provision of staff.[5] The Spinks Report suggested the creation of twenty new posts to ensure adequate training programmes. Though these posts may be found from the earmarked grants, there is evidence that twenty posts may not be sufficient and further funds will have to be provided.[6]

8.14. The Research Councils are playing an increasing role in stimulating and providing for a research base within the universities and polytechnics, and this has a spin-off in the quality of training being provided. While being prepared to provide short-term palliatives to tide the universities over their current financial problems the Councils have stressed that it is imperative that a return is made to the reality of the dual support system.[7] We were concerned about the level of funding available for the support of students' research activities, **and recommend it be raised to a more realistic level.**

8.15. We stress the fact that industry has a role in the funding and provision of training.[8] Many witnesses have pointed to the expensive nature of biotechnology training.[9] In the present climate of public expenditure cuts it is unrealistic to assume that an adequate number of trained biotechnologists can be provided without help from potential employers in the private sector. There are various ways in which this help can be given and one of the roles of the Department of Industry, as lead Department, must be to encourage private industry about their responsibilities in this area.[10]

[1]Appendix 1, point 1.
[2]Qs. 233, 234, 283.
[3]Ev. p. 21, para. 5; Qs. 74–76.
[4]Ev. p. 90, rec. 1.
[5]Ev. p. 21, para. 5.
[6]Appendix 9, para. 12.
[7]Ev. p. 21, para. 5.
[8]Appendix 7, para. 3.
[9]BQ. 2: a 2; Q. 283; Ev. p. 88, para. C.2.
[10]BQ. 9: a 13; Q. 238; Appendix 7, para. 3.

Section 9—Conclusion and Summary of Recommendations

We have made twenty-one recommendations in this report, which are set out below. However, we are deeply concerned over the pressure on the dual support system arising from the failure of the UGC to match the funding of the Research Councils. We consider that our recommendations on this subject are central to the protection of the research base in biotechnology, and should receive the most urgent attention.

We recommend that:

(1) some machinery be established by which the Department of Industry has a formal channel of communications with the University Grants Committee. (para. 4.2.)

(2) the UGC should be represented on the Inter-Departmental Committee chaired by the Government Chemist. (para. 4.11.)

(3) bearing in mind the potential economic importance of biotechnology, a more specific decision-making structure should be established within the UGC for strategic decisions about this subject. (para. 4.11.)

(4) the UGC should monitor the expenditure allocated to create new staff posts on an annual basis for the three years for which they are to be earmarked for biotechnology to ensure that they continue to be used for the purpose intended. (para. 4.12.)

(5) the Department of Industry should review, in consultation with the Department of Education and Science and the Advisory Board for the Research Councils, the present spread of committees with a view to ensuring that strategic decisions in regard to research and development are effectively transmitted through the system and that scarce scientific manpower resources are not wasted. (para. 4.13.)

(6) the Government should make it explicit that the Department of Industry is the "lead" department in biotechnology, and that because of its financial stake in the successful exploitation of biotechnology, the Department should be responsible for its overall promotion. (para. 4.17.)

(7) priority should be given to the restoration of support for scientific and technological research within the dual funding system. (para. 5.12.)

(8) further earmarked support should be given for research in biotechnology, both through the UGC and the Research Council mechanism. (para. 5.12.)

(9) the practice of the Research Councils in earmarking a proportion of their funds for biotechnology should be rapidly improved in future years. (para. 5.22.)

(10) the British Technology Group's monopoly rights over research funded by the research councils should be removed and that, while the Group should have the right to be informed of all patentable inventions, the restriction on scientists taking their research to the open market should be abolished. (para. 6.9.)

(11) the Government should urgently review the relationship between the Medical Research Council and Celltech, particularly as far as exclusivity in access to MRC funded research is concerned, before the Agricultural Research Council proceed any further in their negotiations to set up an agricultural equivalent to Celltech. (para. 6.14.)

(12) an immediate study should be undertaken of the means by which the Centre for Applied Microbiology and Research's facilities and expertise may be utilised more effectively, and that its role as an adjunct to university research should be explored. (para. 6.15.)

(13) the Department of Industry should undertake a study on tax incentives for research. (para. 7.1.)

(14) there should be an increase in Cooperative Awards in Science and Engineering and collaborative awards, the establishment of teaching companies, the provision of funds for post-experience courses, and long-term capital grants for buildings. (para. 7.4.)

(15) the Department of Industry and other bodies should take every step necessary to improve the links between industry and the universities. (para. 7.4.)

(16) methods should be investigated of founding a series of up to a dozen fellowships, similar to that set up by the Royal Society, so that those concerned in biotechnology in industry can have the opportunity of regular contact with appropriate universities. (para. 7.7.)

(17) universities should prepare clear guidelines about proper conduct in relation to academic staff holding consultancies, and publish a list of the consultancies held by their members of staff. (para. 7.17.)

(18) the DES should consult with industry and the universities and report on the extent to which modest revisions of the school curriculum, drawing attention to some applications of biotechnology, would be possible. (para. 8.2.)

(19) training quotas should be arranged to meet the objective of a minimum of one hundred postgraduate trainees in biotechnology a year. (para. 8.9.)

(20) adequate provision should be made as soon as possible for the establishment of new training courses, mentioned in paragraphs 8.6, 8.7, 8.8, and 8.10, and that their progress should be monitored by the Department of Industry. (para. 8.12.)

(21) the level of funding available for the support of students' research activities should be raised to a more realistic level. (para. 8.14.)

ANNEX 1

ANALYSIS OF QUESTIONNAIRE REPLIES

During the course of its inquiry the Committee distributed a questionnaire to a number predominantly of academic institutions. Replies were received from:

1. Professor A E H Emery, Department of Human Genetics, Western General Hospital, Edinburgh
2. Professor B R Rabin, Department of Biochemistry, University College, London
3. Dr J Hindley, Department of Biochemistry, University of Bristol Medical School
4. Professor S J Pirt, Microbiology Department, Queen Elizabeth College, London University
5. Dr M Fox, School of Management Studies, Polytechnic of Central London
6. Professor R R Porter, Department of Biochemistry, University of Oxford
7. Professor R M S Smellie, Institute of Biochemistry, University of Glasgow
8. Professor A T Bull and others, Biological Laboratory, University of Kent at Canterbury
9. Dr D A. Smith, Department of Genetics, University of Birmingham
10. Professor D Sharratt, Department of Genetics, University of Glasgow
11. Sponsors of the proposed Leicester Biocentre, University of Leicester
12. Department of Biochemistry, University of Birmingham
13. Prutec Limited
14. Technical Development Capital Limited
15. Professor K Murray, Department of Molecular Biology, University of Edinburgh

The replies received to each question have been summarised. When necessary, a respondent has been identified by the number assigned to him above.

1. Which areas of biotechnology would you regard as potentially wealth producing in the short to medium term? How far are these areas the subject of research in the UK?

Most respondents gave a reasonably full answer to the main question, but not all dealt with the second one. There was a wide measure of agreement on what are potentially wealth producing areas of biotechnology and, perhaps not surprisingly, these often tended to coincide with the work currently being undertaken by the answering department. Thus generally mentioned were health care materials, such as drugs, hormones, vaccines, diagnostics, and antibiotics; high value chemicals, such as amino acids, nucleic acids, enzymes and vitamins; food and animal feedstuffs; veterinary medicine; agricultural genetics and plant breeding. Less frequently mentioned were areas such as pest control; soil fertility; bulk chemical feedstocks and chemical winning; wastes treatment; and the development of microbial photosynthesis as a means of using solar energy for biomass production to supplement agriculture (4).

When respondents did answer the second question it was most frequently in general terms. British expertise in recombinant DNA technology and in work on monoclonal antibodies were singled out. After listing what were seen as the main research fields (rather than the looked-for end products) one respondent wrote:

> These fields differ in size and significance, but more importantly, in popularity. The majority of the most able are involved in research in molecular biology and genetics while there are shortages of microbial physiologists and biochemical engineers. It will be important to have in this country an interest in plant-cell tissue culture, but we do not see this as a major area of interest in the medium term (8).

The issue of popularity was implicit in another reply. Research on biotechnology as a means to the better utilisation of solar energy was picked out in only one reply, but its author (4) clearly saw this as the most important route in the future to bulk chemical production, as distinct from high value products manufacture. Yet support in this area is seriously insufficient:

> The key to the emergence of biotechnology as a technology to rival chemical technology will be utilization of solar energy for biomass production through microbial photosynthesis. Conventional agriculture cannot provide fuel and chemical feedstocks in significant amounts because it is already stretched to the limit. My department at Queen Elizabeth College is almost alone in the development of the novel reactor technology required to exploit microbial photosynthesis. The support for this novel biotechnology to exploit solar energy is quite inadequate in view of the key importance of the research (4).

2. What constraints are there on research in these areas in universities, polytechnics and Government research laboratories? Are the constraints directly financial or concerned with manpower? What remedies would you propose?

Since the great majority of the replies received came from universities it is scarcely surprising that nothing was said about problems in the Government's own laboratories. Financial constraints stemming from UGC policies were the ones most frequently mentioned; but these, in their turn, could cause manpower problems. On the other hand, some respondents felt that there were no particular manpower problems now (1, 7). However, although this may be true there are serious risks that the best young people will be lost to the USA, France, Germany and Switzerland (3, 10), and when people leave it is impossible for financial reasons to replace them (15). Contributing causes to current difficulties were identified as including lack of support finance for postgraduates and postdoctoral researchers (2, 6, 9) and lack of jobs with career prospects (12). Manpower shortages in particular disciplines were mentioned, such as microbiology (4) and genetic engineering (2), as was also the insufficiency of appropriate blends of qualifications, both as regards individuals and groups (7). Contradictory statements came from those who thought that there were undesirable restrictions on speculative research (9) and, on the other hand, those who wanted more industrial contacts (11) and more contract research (7). One respondent singled out the difficulty in identifying suitable market opportunities as the biggest constraint (14). In so far as respondents suggested specific remedies, they most commonly involved the earmarking of UGC and SERC grants.

3. Are there adequate training facilities for research and development in biotechnology in the UK? If not, what additional provision is necessary?

There was a strong division of view on the main question, but with the view that there are currently adequate facilities predominating. But this is not to say that there was any complacency about the situation. The link between good research and effective training was brought out (8). Conversely, staff cutbacks exacerbated difficulties in reconciling teaching and research (3). The situation may be acceptable now, but financial restraints will exact their toll in time (7). One respondent wanted to see five or six new MSc courses, preferably sponsored by a department of state, and not the UGC nor the SERC, as a more imaginative "third force" (2). Another also favoured such a third party, but preferred it to be industry (18).

4. At what level is training for biotechnology most appropriate? Are new courses needed? How many and where?

There was a large measure of agreement among the answers to the main question. One reply may stand for many:

> Biotechnology is not a discipline in itself and should not therefore be presented as a full 3-year undergraduate course. The most appropriate undergraduate training is provided by broadly-based honours degree courses in biochemistry, genetics, microbiology or molecular biology, but there is considerable scope for such single discipline courses to be broadened for 3rd year undergraduates to provide exposure to various facets of molecular and cellular biology relevant to biotechnology. Training in biotechnology can therefore begin in the 3rd year of an honours degree course in an appropriate science and/or be given in a postgraduate course. New courses are needed. Courses in biotechnology should be offered by about ten universities. These universities should be those that have strength in the supporting disciplines of biochemistry, microbiology, genetics, immunology and biochemical engineering (12).

There were, not unexpectedly, divergences from this view. For instance, other respondents thought that no new courses are required, and that MSc courses have little value (7, 10); they offered a different number of teaching centres from the ten stated above, e.g., six or seven (9) and 12 (4), which latter were named:

> Centres should be developed in London at: Queen Elizabeth College, University College, Queen Mary College and Imperial College; apart from London, appropriate centres could be at Manchester (UMIST), Sheffield University, Kent University, Warwick University, Hull University, Strathclyde University, Cardiff and Swansea University Colleges.

The need for training in collaboration with industry through short and sandwich courses was mentioned several times.

5. Which areas of biotechnology would you regard as requiring long term research support and why? Is funding available for this research in the UK?

In answering this question several respondents drew attention to the replies they had already given to the first question, to which it is related. Not surprisingly, respondents saw the long term as a logical extension of the short and the medium term; and similarly, the problems that will afflict the near future are likely, without a substantial change of policy, to affect the period beyond. A number of respondents suggested that they foresee a trend away from a concentration on high value but small volume products to one of bulk products and processes, such as agriculture generally, protein, fuel and biomass production, polymer manufacture and pollutant treatment (2, 7, 9, 14). Some specific areas were mentioned for their expected wider significance, e.g., the molecular biology of yeasts, because of their widespread use and the fact that they yield no toxic by-products (11). Only one respondent suggested the need for long-term planning (4), but another pointed to the need for periodic reviews: "We do not want to produce fertile ground for the grazing of a new generation of white elephants" (2).

6. Does the dual support system provide an adequate basic support for university research in the biotechnology field?

The answer was a universal and resounding "no". Some typical comments were:

> At present I think there is virtually no University supported research in biotechnology except for salaries of staff. In my own department all such research is supported from outside bodies (1).

> I suggest that the Research Councils now recognise that the dual support system is dead and that they provide the full costs for the scientific programmes they wish to support. The relative needs of the country for graduates in difference disciplines must be carefully evaluated and student numbers in those disciplines which are important for the economy should be expanded. It must be recognised that this is a problem

> that can only be solved at the political level; it is too important to be left to the UGC. I doubt the wisdom of retaining the UGC in its present form, but if it is retained it should be instructed to give detailed reasons for its decisions on the allocation of finances amongst the Universities. If the UGC decisions were reasonably based, there is no reason why they should not be subjected to public scrutiny. The fact that they are unwilling to disclose their reasons would indicate that all is not well (2).

> The UGC contribution does not support more than 2 to 3 weeks' work per annum (3).

> The answer to this question no doubt varies from university to university, but it is our impression that, even with the adjustment by the UGC of the block grants to universities to take account of grants by the Research Councils, that the dual support system is, at best, working only poorly at the departmental level during this time of cutting-back. It is inevitable that savings are being made in the non-pay sectors of university budgets even though costs continue to rise. Because research in biotechnology is not cheap, its development will be hindered, as we have commented above, unless ear-marked funds are made available (8).

> At present UGC funding for research is almost non-existent. Research Council funding would be just about adequate if UGC funding were at the level of 5–10 years ago (10).

> It is well known that the dual support system has been a cripple for some time (15).

The need for additional sources of funds if research programmes are to be continued was often mentioned.

One respondent offered an explanation of how the present situation had arisen:

> The funding available is trivial. Biotechnology emerged when the expansion of the universities was over, hence it has got no more than slight tail end financial support. In contrast, during the university science expansion from 1950–1970 the main beneficiaries were the established disciplines of physics, chemistry, engineering, botany and zoology. In many places there seems to be now considerable spare capacity in those established disciplines. Unfortunately, the university system only seems to be able to provide for a new discipline by expansion and has little or no mechanism to redeploy accommodation and financial resources from one area to another. Now the massive reduction in UGC support for biological science is clearly cutting back biotechnology and narrowing its university base (4).

7. Is the balance of support from public sources (Government, UGC, Research Councils, etc.) and from industrial/commercial sources for research about right?

Only one respondent said that he thought the balance was right; nearly everyone else thought it was wrong in one or more respects. One respondent interpreted the question to refer to the balance among competing priorities within the Research Councils themselves:

> No; it is notorious that the SERC has tied up its resources in established fields particularly nuclear energy, astronomy and other physical sciences and is unable to find adequate resources for biotechnology. The official attitude is that a large telescope, for example, is a conspicuous result of expenditure which makes it more attractive than the development of something less tangible like biotechnology research. I have personally taken up this lack of balance in the SERC scientific expenditure with the last three chairmen of the SERC (Flowers, Edwards and Allen), but all three have dismissed the charge as groundless. The ARC and MRC are well known for looking after their "in house" expenditure before everything else and their contributions to the universities are narrowly based on what is agricultural or medical (4).

Insufficient support from industry was widely commented on. Industry was criticised for seeking only quick returns (4) and for favouring fashionable topics (8). The contrast with the USA was pointed to (6). But another respondent indicated that the problem was perhaps not quite so simple:

> The level of support from industrial and commercial sources for research in university departments varies enormously from institution to institution and from department to department. This can often be influenced by factors such as geography and lack of information. More could be done to encourage contract research and the interchange of personnel between industry and university departments (7).

Another thought that the wrong question was being asked:

> The balance of support from public sources and industrial/commercial sources is not the relevant question. The more meaningful point is that the type of support is actually wrong. Its level is also inadequate. In a large number of areas industrial and commercial interests need to be much more closely identified with the invention opportunities of a fundamental and applied nature arising within the universities (14). Getting access to such public funds as are available seems to be a needlessly complex task. More and better guidance to applicants is required (11).

8. Are there any comments you would make about the kind of financial support which is available, e.g., the need for more long term support for basic research or for more project-orientated research?

The overriding impression given by the answers to this question was that respondents wanted to see dependable support extending beyond the short term. Thus the need for long-term appointments was mentioned (6) as were more earmarked studentships and a career structure for researchers (12). While the desirability of having more project-linked research, possibly subject to periodic peer review, was indicated (2, 13), it was at the same time acknowledged that this would imply greater funding from industry; but this should not detract from the independence of academics to pursue their long-term work (8). It is vitally necessary to preserve the strength of basic research and not to sacrifice this in favour of short-term gains (7, 10). One suggestion was that support for buildings and major facilities should come from public funds and that industry should sustain the research projects themselves (11). Another was that help for the inventor in getting his findings into development is what is greatly wanted. This means more than money alone; it also means production and marketing help (14).

9. Do adequate mechanisms exist for transferring research (whether carried out in universities/polytechnics or Government research laboratories or industry) from the laboratory into the market place?

A clear division of opinion also emerged on this question. But whereas those respondents who thought that the transfer mechanisms were adequate merely said so, those who thought they were not usually explained their views at greater length, thus perhaps leading to the conclusion that the latter had the stronger case. A lack of initiative and of a willingness to take risks on the part of industry was commented on (6, 9, 13, 14), as was the lack of contact between the universities and industry (worries about confidentiality were mentioned in this connexion) (8). The attitude of industry to academic innovators was criticised (12) and its failure to recognise the importance of strategic research (4), but there was also academic uncertainty about what industry was likely to be interested in (9, 14). Some respondents gave the impression that there was a factor in the British academic psyche that virtually impeded such transfers. The remedy was seen by one respondent as requiring new institutional arrangements (13), but by another as being primarily the responsibility of industry:

> This is the most difficult but the most crucial area of all because the natural facility that the British have in research does not extend into the successful commercial development of the fruits of research. This, therefore, is an area that requires very special attention.

> One of the motivating principles behind the founding of the Leicester Biocentre is the recognition that technology transfer is a job that must be done mainly by industry and can only be done properly if industry establishes closer links with universities. There is no reason to believe that there will be insuperable difficulties in manufacturing new products, but there is every reason to fear that severe problems will arise when it comes to economic exploitation unless industry develops new skills. These are problems that only industry can solve (11).

10. Are there disincentives for industrial investment in research and development in biotechnology in the UK?

Not many of the respondents felt able to comment usefully on this question since it related exclusively to industrial R & D. Again the timidity of industry with regard to long-term risk taking was raised; British industry contrasts badly in the respect with overseas companies (3, 6, 12, 15). Contributing factors identified include the current economic climate, the tax regime, high interest rates and lack of staff mobility between industry and academe (7), and also a spill-over effect from the declining investment in academic research (15). One respondent singled out the repressive effects of the European Community impost that effectively killed off the biotechnological route to fructose production (4). Finally, another drew attention to one factor in the past and a danger in the future:

> The NRDC has frustrated industrial investment in several instances by causing undue delays or asking for disproportionately high royalties when the scale of investment required by industry is taken into account. There is a danger that government-backed organisations set up to develop and exploit research from the universities may compete with and so frustrate industrial investment, while lacking the ability to follow the R & D through in every case (13).

11. Do you believe that the UK is missing opportunities for research and development in biotechnology which are being taken up by industrial competitors, e.g., in the USA or Japan, or is our research base sufficiently strong to maintain our position?

A strong sense of despondency was communicated by the answers to this question:

> Yes. Our research base is strong but our ability to apply this base is historically weak . . .
>
> The UK is missing opportunities in biotechnology.
>
> The UK is missing and has already missed major opportunities . . .
>
> Yes, we have probably already missed the boat.
>
> Our research base is sufficiently strong. However, British research is still more likely to be exploited by the US or Japan than by UK companies (13).
>
> Yes, opportunities are being missed and almost certainly the UK is lagging behind the United States, Japan and possibly other European countries particularly at the levels of enthusiasm, speed, efficiency, development and production. These deficiencies cannot be blamed simply on not having a strong research base (9).

12. Do you have any comments on the present position in regard to patent arrangements and/or the role of NRDC?

Not all respondents felt able to comment usefully on these matters, but those that did had pointed things to say. The most significant of them are quoted below:

> Patent arrangements are expensive and yet offer little protection for ideas unless they are world-wide and policed. Universities on their own are rarely able to cover patents adequately. BTG have a great opportunity in handling patent arrangements and in

encouraging the development of biotechnology within both universities and commercial companies. The role of the NRDC in recent years has left much to be desired (12).

The universities should be able to choose between the services of the NRDC and the alternative of being able to take out patents themselves with the assistance of patent agents other than the NRDC. Neither the NRDC nor any other government agency should be given a monopoly on rights. This conflicts with the promotion of industrial co-operation by introducing a layer of bureaucracy between the interested parties which can and has proved prejudicial to new ventures (13).

We hope that the British Technology Group will do better than NRDC. We would, however, urge that more scope should be given to university industrial liaison companies for the exploitation of patents. If Research Councils could be permitted to grant patent rights directly to these companies, the essential functions for which NRDC was created would be preserved, the proceeds would benefit this country and possibilities for exploitation would not be neglected. Indeed, the enthusiasm necessary to carry a project forward would be generated within a university in a way which a large organisation cannot match. It would always be possible for the university company to negotiate with NRDC, if that was the best way to exploit an opening, but it should not be obligatory. We believe that university staff in the present financial climate would welcome the opportunity to be more closely involved in the exploitation of their inventions, especially if they felt it would benefit their institutions as well as themselves (8).

The situation here is confusing and unsatisfactory. One of the factors that encouraged the collapse of the original Leicester Biocentre scheme was the demands made by NRDC in respect of the distribution of royalties from patents. As an example of confused thinking, financial support can only be obtained from SERC if the work is not profit-oriented, although the ultimate purpose of new technology is wealth creation! Indeed the agreement which has to be signed to obtain SERC funds assumes increased profitability since it contains a clause which makes royalties payable to NRDC on sales of products or the use of processes developed from the research. The Government's deep concern over patents seems somewhat excessive, bearing in mind the difficulty and expense of obtaining them and the small proportion that actually yield worthwhile profit (11).

As we mentioned in our report we regard the role of NRDC as it is now exercised as being obsolete and we drew attention to very progressive new national schemes which have been started in recent years in France and Sweden . . . I would conclude by saying that, whereas NRDC's policy tends to be that of a bank which seeks a relatively early return on its investment, the French and Swedish schemes rightly take a long-term view in order to encourage a healthy innovation climate. The danger which NRDC represents is all the greater because it has a monopoly position concerning the exploitation of Research Council funded research and, in the first place, we have recommended that this monopoly should be terminated. In the second place, we would like to see two new initiatives. Firstly, a national de-centralized scheme with the local offices having powers to give relatively large sums for one project (£100,000 in France and £400,000 in Sweden), with decisions being made with 3–4 weeks. The money can be spent along the complete innovation chain from patenting at the beginning to marketing at the end and this, of course, provides a very coherent approach (5).

The present patent arrangement, whereby the NRDC has patent rights on practically all government funded research, is a major disincentive in the UK system. It is a negative incentive system. If the university worker puts in a large amount of effort to produce patent exemplification he has no incentive to complete. What is required is that the NRDC should operate as competitively as any other venture capital

> operation would. Patent and commercial rights should be vested within the Universities and both Universities and inventors should negotiate on an individual basis. Patent help should be provided as an additional service. Inventors and Universities should be encouraged to participate in the commercialisation of invention. This will lead to skills being developed on a regional basis and will promote the establishment of business on a much wider basis. The present centralised arrangements are inadequate for the total potential (14).

> I have no recent personal experience with the NRDC, but in the past I have not found them to be particularly enterprising in their outlook and they do not enjoy a good reputation amongst either academics or industry. Their attitude to the support of research in Universities is niggardly and there is no reason to take one's research proposals to them instead of the Research Councils, in fact quite the contrary (15).

See also the summary of the answers to question no. 10.

13. Should biotechnology be the subject of a special Government initiative, as recommended by ACARD, or should its development be left primarily to the private sector as recommended in the Government's White Paper?

With few exceptions all respondents were in favour of a special Government initiative, generally in association with industry. When translated into practicalities respondents usually meant more research funds and incentives to industry, perhaps as tax reliefs (7). Industry lacks initiative, vision and interest and is waiting for a lead (3, 4). However, some replies sounded a warning note, for instance, there seem to be a great many committees and working parties concerned with biotechnology; how productive are they? (10). Others noted Government's poor record in finding commercial winners:

> The British industrial scene is littered with Concordes and Advanced Passenger Trains, projects which were technically brilliant, were intended to generate wealth, but which instead have become serious drains on the public purse. This has happened principally for two reasons. First there was totally incorrect estimation of development and manufacturing costs. Secondly there was misunderstanding of commercial factors.

> If biotechnology is to create wealth for Britain, these problems must be avoided. It is essential to realise that the profitable commercial exploitation of biotechnology will depend at least as much on accurate market research and rapid development work as on successful fundamental research. It is here that industry has heavy and unique responsibilities.

> There is much to be said, at this stage, for there being a partnership between Government and Industry, with the former acting as a catalyst to industrial activities through measures such as grants and tax incentives (11).

> A Government initiative is needed because the country lacks entrepreneurial drive. Unfortunately, government bodies do not have a very impressive record for picking the commercial winners emerging from a research laboratory. The initiative should be restricted to improving the fundamental scientific base in our Universities and any attempt to define commercial targets should be resisted—this can only be done by those disciplined by the realities of the marketplace (2).

These two extracts suggest that the respondents view Government's role as one of midwife rather than parent.

ANNEX 2

GLOSSARY

Amino acids	:	the component parts of proteins; there are 20 common acids forming a chemical family; examples are glutamic acid and lysine
Antibody	:	blood protein that reacts upon a foreign substance (antigen) so as to counteract its effects or destroy it
Antigen	:	substance identified as foreign by humans or animals and combatted by the production of an antibody
Biochemistry	:	chemistry of living matter
Biomass	:	plant and animal material
Chromosomes	:	thread—or rod-shaped-elements within a cell nucleus which embody hereditary factors
Clone	:	cell descendents derived from a single cell by repeated divisions
DNA	:	deoxyribonucleic acid; the genetic material found in all living organisms and a major component of chromosomes
Enzyme	:	complex proteins that trigger chemical changes in living cells by acting as catalysts; they are the active agents in fermentation processes
Eukaryotes	:	higher, structured cells; all multi-cellular organisms are eukaryotic, as are unicellular forms such as yeasts and protozoa
Fermentation	:	a biochemical change brought about by an enzyme, e.g., the conversion of grape sugar into alcohol
Gene	:	the hereditary unit; the segment of a chromosome that codes for a specific protein
Genetic codes	:	biochemical basis of heredity whereby the amino acid sequences in proteins are determined from the structure of DNA molecules
Genetic engineering	:	the technology whereby the hereditary apparatus of a living cell is altered so that the cell can produce more or different substances or perform new functions
Genetics	:	science of heredity
Hormone	:	"messenger" molecules of the body that help to co-ordinate the actions of several tissues, producing a specific effect on cells remote from their own point of origin
Hybridomas	:	result of the fusion of antibody-producing cells and tumour cells; the source of monoclonal antibodies
Immobilised enzyme	:	enzyme chemically bound to a solid matrix or entrapped in a small-pore gel so that it is easily separable from other substances
Interferon	:	protein released by cells after infection by a virus that protects other cells non-specifically

Microbiology	:	branch of biology dealing with microscopic and sub-microscopic organisms
Monoclonal antibodies	:	antibodies of a single, unique composition
Nucleic acid	:	basic chemical, polymeric substance for hereditary information
Peptide	:	short amino acid chain
Plasmid	:	ring-shaped nucleic acids within cells with hereditary information that replicate independently of the chromosome
Protein	:	large molecules consisting of amino acid chains; the functional and structural components of cells
Recombinant DNA	:	DNA molecules of differing origins that have been joined together by biochemical techniques
RNA	:	ribonucleic acid; serves to translate the genetic coding of DNA into a new protein molecule
Vaccine	:	a modified micro-organism or virus of a particular disease and used for preventive inoculation
Vector	:	a transmission agent; in recombinant DNA specifically a plasmid or virus that can carry a foreign DNA into an host cell
Virus	:	an infectious agent that requires an host cell in order for it to reproduce; it is composed of either DNA or RNA wrapped in protein; human diseases caused by viruses include influenza and measles.

ANNEX 3

PRINCIPAL AND OTHER RECOMMENDATIONS OF THE SPINKS REPORT

Principal recommendations (with reference to paragraph numbers) are:

R1. The Research Councils should substantially increase their support for biotechnology. But because the subject cuts across their areas of interest and expertise and will point up gaps between them, the Councils should also, with the Advisory Board for the Research Councils (ABRC), set up a Joint Committee for Biotechnology. With the support of a Director/Co-ordinator to stimulate new projects in universities and elsewhere, this Joint Committee should develop and co-ordinate a coherent programme of biotechnology research. Building on their present and forward commitments for the subject, the Councils should together reach a spend of at least £3 million annually, the minimum we believe is now required. The Research Councils, with the Joint Committee, should consider making a requirement that a proportion of the grant applications from universities should show evidence of industrial interest. (4.6)

R2. The activities of Government Departments in relation to biotechnology should be co-ordinated; and a coherent programme of industrial research and development involving industry, Government research establishments, universities and Research Associations should be pursued at an annual expenditure of about £2.5 million (including existing projects). An inter-departmental Steering Group should be established to meet these objectives. This would be complementary to and, through common membership, well articulated with the proposed Joint Research Council Committee and should work closely with the National Research Development Corporation (NRDC). Technical support for such a Group might be provided by a unit comparable to the Energy Technology Support Unit at Harwell. (4.8)

R3. We do not support the establishment of a new Government research establishment for biotechnology. But the Steering Group should consider how more use could be made of all the existing establishments, eg the Centre for Applied Microbiology and Research (CAMR), AERE Harwell and the Warren Spring Laboratory (WSL), to advance biotechnology. For example, the Department of Industry should co-sponsor CAMR to strengthen the industrial side of the CAMR programme. (4.11)

R4. The Confederation of British Industry, the Association of the British Pharmaceutical Industry, the Chemical Industries Association, the Food and Drink Industries Council and other trade associations, including that proposed in R5, should actively seek to identify opportunities for advances in biotechnology in the fields of potential interest to their members. They should then take effective steps to inform members of neglected opportunities and to inform Government, trades unions and others of any constraints that need to be removed. This last step might be pursued with in the appropriate Sector Working Parties of the National Economic Development Office as recommended in the ACARD report "Technological Change: Threats and Opportunities for the United Kingdom". (4.12)

R5. A trade association of suppliers of process plant and equipment should be formed to provide, *inter alia,* for closer contact between suppliers and research scientists. The proposed trade association should give particular attention to the export potential provided by developing countries and the way it is best pursued. (3.14, 4.13)

R6. The National Enterprise Board in conjunction with the NRDC should investigate the possibility of using some public funds to establish a research-oriented biotechnology company of the kind now taking shape in the United States. A sum of £2 million annually for five years should be sufficient to determine its value and establish the scale of further investment. (4.14)

R7. We strongly support the initiative of learned and professional bodies in establishing the British Co-ordinating Committee for Biotechnology (BCCB) and commend it to industry and Government as a valuable forum. It should develop close contact with the process plant industry. Industry should do more to assist the BCCB financially and be more active in its support for university research. (4.13)

R8. The University Grants Committee (UGC) and the Research Councils, with the backing of the universities, should support the expansion of a limited number of centres of excellence in biotechnology from the best existing in universities. A minimum of 20 new teaching and research posts should be created over the next five years with a capital investment of around £2 million to provide adequate laboratory facilities. We ask the Department of Education and Science (DES) to note the need for additional finance. (4.15)

R9. The Committee of Vice-Chancellors and Principals (CVCP), the UGC and the Committee of Directors of Polytechnics should, with the DES and the Department of Employment where appropriate, consider urgently how to provide an adequate, appropriately trained workforce to match the expected growth of biotechnology and how to encourage greater interaction between departments and undergraduate courses in the biological, chemical and engineering sciences. The DES should take account of these likely manpower demands in its forward planning of the provision for higher and further education. Young scientists and engineers should be made aware of the potential benefits and opportunities which biotechnology can provide. (4.17)

R10. Collaboration should be fostered between universities, Research Councils and industry in postgraduate training in biotechnology. The Science Research Council's CASE award scheme provides a suitable example of a pattern for achieving collaboration of this sort. Attention should also be given, by the Councils concerned, to the promotion of collaborative arrangements with industry at post-doctoral level, for example by encouraging the use of industrial funds to support research workers from industry working in Research Council and university laboratories. (3.3, 4.15)

R11. We wish to see the NRDC play a more entrepreneurial role in the support and encouragement of innovation and the provision of funds for development in a field where inventions are often not readily patentable. To this end NRDC should expand its staff resources for biotechnology, re-examine the financial awards and incentives for academic inventors, and be as much concerned with the creation of new companies as with matters of industrial property. NRDC should lead a study with the UGC, CVCP and the Research Councils to review existing and potential ways of encouraging academic inventors in the United Kingdom and to consider practice overseas. (4.18, 4.19). The NRDC should also continue to pursue with the Patent Office the problem of patents as they relate to micro-organisms. (3.11)

R12. If the opportunities offered by genetic manipulation are to be seized, the Government should, as new research defines more precisely the nature of the hazards involved, modify the regulatory regime appropriately, in consultation with others abroad. The Genetic Manipulation Advisory Group (GMAG) and the Health and Safety Executive should continue as rapidly as possible to reduce constraints upon genetic manipulation experiments while maintaining an adequate degree of safety; to introduce procedures to ease industrial application of these techniques; and to keep the controls in the United Kingdom and other countries under review. (4.20)

Our other recommendations and comments that may call for action are:

R13. There should be continued support for the biotechnology programme of the Department of Energy. The Department of Trade, in conjunction with the Department of Energy, should review opportunities for export of process plant in the field of biomass and waste for energy and should help co-ordinate United Kingdom policy in this field in relation to the EEC. (4.23)

R14. The Ministry of Agriculture, Fisheries and Food, with other Departments, should review the pattern of agricultural production in the United Kingdom in the light of the prospects of using some agricultural products for industrial feedstocks and replacing the production of some agricultural commodities by industrial processes. (4.14)

R15. We commend to the Government the recommendations on financial assistance for small firms in the ACARD report "Industrial Innovation" (3.19). More particularly, the Department of Health and Social Security should consider whether changes in its purchasing policy for the National Health Service would be justified in order to support the entry of small firms using biotechnology into the market. The Department should also undertake a study on possible new testing systems for medicines, food additives, etc with a view to reducing the costs and duration of development. (4.15)

R16. The Department of the Environment in conjunction, as appropriate, with the Department of Industry, the National Environment Research Council (NERC) and other Councils should increase support for biotechnology research relating to effluents, waste disposal, materials recovery, etc and work with local authorities, relevant private industry and research establishments such as WSL, AERE Harwell and the Water Research Centre in studying the potential role of biotechnology in these and other public service fields. (4.26)

R17. If the research programme in biomolecular engineering being prepared by the European Commission is taken up by the Community, the United Kingdom should seek the maximum return from it. Separately, the Government should seek fiscal regulations within the EEC which will allow the use of agricultural feedstocks for industrial biotechnology and not impede the introduction of new processes based on biotechnology. (4.27)

R18. We are concerned that, if agreed in its present form, the draft EEC Directive on genetic manipulation would create a slow and inflexible system of controls based on premises now no longer held by a majority of countries within or outside the Community. The need for a directive should be reconsidered in the light of new knowledge of the conjectural hazards involved. (4.21)

R19. We have concluded that machinery is required to ensure the future of culture collections of living micro-organisms through long term financial support. The proposed interdepartmental Steering Group for Biotechnology should study the way in which existing collections can best be maintained and the merit of establishing further national or international collections. (4.10)

R20. We welcome the Science Research Council initiative to establish machinery to stimulate growth in biotechnology research, particularly in the area of strategic applied research. We believe that capital expenditure of £1·5 million and recurrent annual expenditure of £1 million would be wholly justified and should be achieved as soon as practicable, as a component of the programme proposed in R1. (4.7)

R21. We commend the Agricultural Research Council's continued support for the application of new techniques of genetic manipulation in plant breeding. In common with the Medical Research Council, the ARC should vigorously pursue DNA research applications to improve and create biological products. (4.23, 4.22)

R22. The Research Councils should, through the Joint Committee for Biotechnology, review their roles in relation to industrial development based on biological processes so that their staff are aware of the desirability of creating, wherever possible, a national return for their efforts through industrial development. (4.22)

R23. The proposed Joint Research Council Committee and Steering Group should consider how to encourage international collaboration in biotechnology to the benefit of the United Kingdom. (4.28)

R24. Finally, biotechnology is a rapidly developing subject and the Government should commission a further detailed study to review the position in 4 or 5 years' time. (4.9)

ANNEX 4

National Enterprise Board press release

BIOTECHNOLOGY

A company, shortly to be formed with a share capital of £12 million, is to specialise in the rapidly developing business field of biotechnology. One of its objectives will be to make available for use by industry, a range of products and know-how derived from the outstanding research position in biotechnology of the United Kingdom.

The founding shareholders of the company are likely to be the National Enterprise Board, Prudential Assurance Company, Midland Bank, The British and Commonwealth Shipping Company Limited, and Technical Development Capital Limited, a member of the Finance for Industry Group. The NEB and its partners are engaged in establishing the details for co-operation with the Medical Research Council and other scientific institutions with the intention of translating scientific knowledge and skills into commercial ventures.

The Secretary of State for Industry has already given his approval for an investment by the National Enterprise Board in this company.

The company will shortly announce further details relating to its structure, management and immediate commercial objectives.

23 July 1980

LIST OF WITNESSES

Wednesday 24 *March* 1982 (HC 289-i)

The Royal Society
Sir Arnold Burgen, FRS, Professor Patricia H Clarke, FRS, Professor B S Hartley, FRS and Professor M D Lilly

Wednesday 21 *April* 1982 (HC 289-ii)

Agriculture Research Council
Dr R Riley, FRS and Dr J Ingle

Medical Research Council
Dr T Vickers and Dr Victoria Harrison

Monday 26 *April* 1982 (HC 289-iii)

British Technology Group
Dr J C Cain, Mr D W Beattie, Dr R F Homer and Mr P R S Hartnack

Prutec Limited
Dr D Allam and Dr D Copsey

Technical Development Capital
Dr J Walker

Monday 10 *May* 1982 (HC 289-iv)

Science and Engineering Research Council
Professor J F C Kingman, FRS, Dr W G Potter and Dr A T James

Wednesday 12 *May* 1982 (HC 289-v)

The Biochemical Society
Professor S V Perry, FRS and Professor R D Marshall, FRS

The Society of Chemical Industry
Professor J Melling and Mr P P King

The Society for General Microbiology
Professor D C Burke and Professor C M Brown

Monday 24 *May* 1982 (HC 289-vi)

Department of Industry
The Rt Hon Patrick Jenkin, MP and Dr R Coleman

Wednesday 26 *May* 1982 (HC 289-vii)

Department of Education and Science
Mr William Shelton, MP and Mr R H Bird

University Grants Committee
Dr Edward Parkes, Professor G R Higginson, Professor J Gareth Morris and Mr N T Hardyman

LIST OF MEMORANDA INCLUDED IN THE MINUTES OF EVIDENCE

(HC 289-i to HC 289-vii) *Page in daily part*

What is the basis for some memoranda being included in the Minutes of Evidence, others included here?

LIST OF APPENDICES TO THE MINUTES OF EVIDENCE

(B Number denotes original reference number given by the Committee)

Number *Page*

MEMORANDA SUBMITTED BY:

APPENDIX 1

Letter from J F Davidson FRS, University of Cambridge, Department of Chemical Engineering, to the Clerk to the Committee

BIOTECHNOLOGY (B 3)

I am writing in reply to your letter of 16 March. I should say that the replies below are specific to this department and a reply giving the general University view may be forthcoming later.

I would like to make two main points.

1. *Overloading of teaching staff.* Out of an establishment of 12 teaching officers we now have one vacancy and there will be another soon because of the University's early retirement scheme because of the cuts in university finance. We are not able to fill the current vacancy and it is unlikely that we shall be able to fill the impending vacancy. This would leave us with a teaching staff of ten to deal with 50 students per annum and a student/staff ratio of the order of 15 to 18, which is about twice the national average for engineering. This makes it difficult to support new initiatives in biotechnology. Nevertheless we have succeeded in establishing a biotechnology course for chemical engineers with assistance from the Department of Biochemistry, so that about 10 per cent of the final year course for chemical engineers is biotechnology. Also, 10–15 per cent of our research students, see the enclosed booklet,[1] are working on biotechnology. Lastly, we have a new SERC-supported worker, Dr Chase, whose project is wholly concerned with biotechnology. However, the further development of these early initiatives will be much constrained if we are not able to fill the above-mentioned vacancies.

2. *Supply of research students.* In the past about 50 per cent of our research students were from overseas, of excellent quality. Subsequent to the very substantial increase in overseas student fees about two years ago, the number of applications from overseas has declined and a limitation of our research in biotechnology, as in other fields, is the supply of good research students. We are unable to attract sufficient UK students because the maintenance grant from an SERC studentship is so very much less than the salary which our graduates can expect to earn in industry. An urgent need is to find a way of paying UK research students more than they can get from an SERC maintenance grant.

1 April 1982

APPENDIX 2

Letter from A W Holmes, Director, The British Food Manufacturing Industries Research Association, to the Clerk to the Committee

BIOTECHNOLOGY (B 7)

I would like to make three brief points for consideration by your committee:—

1. There are substantial problems in securing finance for biotechnology within Research Associations. SERC finance is not available to us and any funding from the Department of Industry requires an equal input from industry. At present the future of biotechnology within the food industry is somewhat uncertain and as a result industry is not prepared to provide funding. Within this laboratory we have ideas which might well change the future of biotechnology for the food industry but these are long-range ideas and do not at present appeal to the industry. The consequence of this situation is that we are unable to secure funding and the ideas cannot be pursued.

[1]Current Activities in the Department of Chemical Engineering, November 1981: Not Printed.

LETTER FROM DR J EDELMAN, RHM RESEARCH LIMITED, TO THE CLERK TO THE COMMITTEE

2. We are aware of some university work which could have an impact on the food industry. However, by and large the universities are unaware of the significance of the food industry and show little interest in developing in this direction. There is no easy mechanism for identifying and exploiting relevant university work.

3. Any new biotechnology development applicable to food will have to receive approval of the Novel Foods Committee. The composition of this committee has not yet been announced but we are seriously concerned that the industry representation on it might not be sufficient to ensure that the toxicological testing requirements are reasonable. There is no doubt that if full toxicological testing is required for each and every development applicable to food, no exploitation will be possible. Similarly, we are concerned that the committee should arrive at decisions in a reasonably short time span. Since this is a newly formed committee one can only express anxieties as to developments which might occur.

We will, of course, be happy to expand on these points should your committee so wish.

13 April 1982

APPENDIX 3

Letter from Dr J Edelman, RHM Research Limited, to the Clerk to the Committee

BIOTECHNOLOGY IN THE UK: TRAINING, RESEARCH AND INDUSTRIAL APPLICATION (B 13)

Thank you for your recent letter. I respond as a member of the Food Industry involved in the devlopment of a large biotechnology programme.

EDUCATION

Biotechnology at Universities is, in our view at this Research Centre, more suited to postgraduate study and needs a vigorous basic science education in one or more of the existing disciplines: biochemistry, biophysics, microbiology, genetics, etc., etc. Clearly, in order to provide for this, the Universities have to be financed and staffed at a suitable level.

RESEARCH COUNCILS

Research Councils have shown an awareness of biotechnology, particularly SERC which has set up a Biotechnology Directorate, but the finance available to this area may well be insufficient in the long term, since so much of the SERC's income is expended on existing SERC establishments, particularly in the area of Radio Astronomy, and at Harwell. If no more finance is forthcoming, then perhaps as a nationwe will need to make a choice between our currently heavy investment in "big" physical science which, while scientifically exciting, may have less potential as a wealth generator than does biotechnology.

INDUSTRIAL RESEARCH

In the food industry, the costs of long term basic research is particularly difficult to sustain owing to the low overall profitability of the industry. Government support, through MAFF, is particularly welcome and should be increased substantially from the current annual figure of some £5 million to, say, three times this level of support.

INDUSTRIAL APPLICATION

It is in this area that the major problem of finance arises. The capital sums necessary for large-scale biotechnology developments are usually far in excess of those normally envisaged by the food industry. Combined with the high risk involved, the financing of commercial-scale biotechnology plants in the food area is the main stumbling block. Without some significant new sources of funding, a number of biotechnical research and development projects with great potential will founder or be taken over by overseas competitors.

30 April 1982

APPENDIX 4

Letter from D W A Sharp, Chemistry Department, the University of Glasgow, to the Clerk to the Committee

BIOTECHNOLOGY IN THE UK: TRAINING, RESEARCH AND INDUSTRIAL APPLICATION (B 17)

Your letter indicating that the Education, Science and Arts Committee will be considering Biotechnology as a matter of urgency this spring, has been passed to me, and on behalf of the Faculty of Science, University of Glasgow, I would like to make some points to you. You have already received detailed comments from some of my colleagues at Departmental level.

1. We believe that training in Biotechnology is best carried out by in-depth training in the specialist disciplines (e.g. Biochemistry, Chemistry, Genetics, Immunology, Microbiology, Botany, Cell Biology) at first degree level followed by research training at PhD level on a Biotechnology-oriented problem. We are strongly against specialised training in Biotechnology at first degree level and this training is unlikely to lead to the depth required for significant understanding of and work in the area.

2. We draw particular attention to the degree structure of Glasgow University (and other comparable Universities) with breadth in the first two or three years because of entry to Faculty (and the experience of a range of cognate disciplines) followed by specialisation for one or two years.

3. The range of biological sciences at Glasgow University and their expertise is particularly appropriate for development of persons trained in Biotechnology. The University has made application to UGC for earmarked funds in this area. The close relationship between Departments in the Faculty of Science and Medical Departments and the strengths of the latter could lead to important developments in the areas of Biotechnology which are close to Human Biology.

4. Clearly individual specialists need appreciation of the team effort needed for successful prosecution of an interdisciplinary study such as Biotechnology. SERC should set up workshops for those undergoing research training in this field to emphasise the interdisciplinary character. The workshops should emphasise the importance of finance and sales in a successful application of Biotechnology development

5. Research in Biotechnology is expensive and uses sophisticated equipment, much of it controlled by microprocessors (indeed there is already work in progress in Glasgow University in the direct interfacing of cells and electronic components). The teaching of science subjects to international standards requires equipment only marginally less

expensive than that required for research and often the same equipment is used for teaching and research. The successive cuts in University spending, together with lack of decision within and between Universities to earmark priorities, have led to a grave crisis in funding, so that fundamental teaching and research are in grave danger.

6. We can see the attraction of short term target oriented research, but would urge the Committee to realise that long term successful research can bring far greater economic net benefits to the UK. All indications are that research support spending in the UK is dropping and is now below our major competitors in innovation (Japan, USA, possibly Germany).

If there are any points which require clarification or other points which arise, I would be very pleased to try to help.

10 May 1982

APPENDIX 5

**Memorandum Submitted by the Brewing Research Foundation
Research Establishment**

THE PROTECTION OF THE RESEARCH BASE IN BIOTECHNOLOGY/BIOCHEMICAL ENGINEERING (B 18)

INTRODUCTION

The current interest in biotechnology and the belief that it will expand very considerably is based upon three factors:

(i) The raw materials can be obtained from renewable resources.

(ii) Biotechnological processes appear likely to be economical against the chemical processing of vegetable materials.

(iii) A wide range of possibly valuable products is being defined by both traditional biological methods and through genetic manipulation.

As with most areas of technology local and global political considerations will undoubtedly distort both the areas of development and the rates of progress, e.g. alcohol fermentations are important independent of the overall economics. In general biotechnology can be divided into three definable areas described here as large, medium and small, terms which refer to the scale of industrial development rather than the size of the individual production units which might be built:

(i) Large scale, where biotechnology must compete initially with petroleum and subsequently with coal, as a primary source of carbon compounds for fuels and high tonnage industrial products.

(ii) Medium scale, where biotechnology must compete with petroleum style technology (whether the carbon source is petroleum, coal or vegetable) to produce either the commodity chemicals currently in use or substitutes for them, and with agriculture to produce natural products such as proteins and lipids.

(iii) Small scale, where specifically biochemical products are produced for which no other routes can currently be foreseen.

Memorandum Submitted by the Brewing Research Foundation, Research Establishment

Small scale processes seem certain to continue their present rapid proliferation and growth: their products offer such improvements in medical practice and for industrial processes that the cost of the products is not a deciding factor in whether the products are developed but in which manufacturers succeed. The medium and large scale processes are probably not currently viable economically except in a few cases, e.g. some organic acids where production is truly economic, alcoholic drinks, and acetic acid for human consumption. However, it is likely that the next twenty years will see the establishment of large scale microbiological processes with vegetable materials as feedstock. These processes will:

(i) Produce primary materials as fuels and feedstocks for conversion to commodity chemicals, though whether the later conversion is chemical or microbiological will depend upon processing economics.

(ii) Produce a range of commodity chemicals directly from vegetable substances rather than via some primary product such as ethanol.

General Situation

The technical development of a process to plant status, as opposed to the definition of a method in a laboratory, demands the evolution of know-how, experience and equipment for the unit operations involved to standards appropriate for the scale of the operation. Whilst such evolution is possible on a one-off basis the cost and time involved is seldom sustainable. Consequently only operations applicable to a range of processes develop to a stage where the information on their characteristics and the equipment they require is widely available. Conversely the applications must be sufficiently numerous to justify economically the efforts of process developers and equipment makers which are necessary to the establishment of a unit operation of wide application.

The preparation and processing of microbiological products has currently available to it a rather limited range of developed processes and unit operations. Where the scale is large and consequently a high standard of development is needed, the processes depend essentially on the application of techniques and of equipment developed elsewhere. *For the future large scale development of the industry the costs of these operations represent a major restraint*. Specialist techniques more suited to the industry are needed and inspection suggests their development should be possible.

For the product processing stages there are a number, and prospectively a large number of products where established commercial scale unit operations are not applicable or not the most appropriate. The range of laboratory techniques which might be developed to plant scale is, however, extremely wide. Until an appropriate range of techniques is available on a commercial scale, with equipment and information on their characteristics and economics accessible to process developers, the development of the industry will be hampered. Evolution and need will generate a repertoire of developed operations, given time. It should however be possible to accelerate this progress and with it the development of the microbiological industry by defining, on the basis of foreseen unfilled needs and suitability for plant application, process operations which, if developed, would be commercially attractive.

(a) *Enabling Technology for Process Development*

The transition from laboratory to commercial scale is a matter of reducing the cost of achieving effects. This is done by increasing the scale of operations, by modifying or changing the unit operations used, by changing the basic process or by permutations of these options. Increasing the frequency of operation on the same scale is hardly ever an attractive option in bulk processing (as opposed to mechanical processes) and is only used when no alternatives can be evolved. It is thus normally impossible to develop a commercial scale method without altering variables which control the effects of the process. Understanding the nature and effect of these variables is thus essential for successful production scale development.

MEMORANDUM SUBMITTED BY THE
BREWING RESEARCH FOUNDATION, RESEARCH ESTABLISHMENT

In downstream processing there are available a wide range of laboratory processing operations for which plant scale equivalent or alternatives will be required but are not currently available. In the financially important area of processing the fermentation broth the controlling variables are not well understood or even quantifiable by present technology and current practice only uses a very limited part of the potential range of methods. There are also specific operations which can be identified, e.g. biomass drying which because of their high cost are limiting the development of the industry.

The processes concerned are essentially controlled by the physical or physico-chemical properties of the systems which have to be handled and the relation of these properties to the mechanisms of the unit operations used. There is consequently a need for work on the physico-chemical nature of broths and their constituents and of specifically microbiological products which cannot be isolated by conventional chemical processes, i.e. of large and chemically and physically delicate molecules—and on the physical mechanisms of unit operations in relation to these properties. Improved understanding of these factors is a necessary basis for the improvement of downstream processing technology both in terms of present operations and in the selection and development of new commercial scale operations to meet future needs and improve present performance.

(b) *Examples of Innovation*

That innovation is both possible and practicable is illustrated by a number of developments in recent years which have achieved both processing and commercial acceptance within downstream biological process engineering and by others for which acceptance appear inevitable.

(i) *Liquid CO_2 Extraction*
This process has been developed for the extraction of bittering substances from hops as an alternative to extraction based upon organic solvents.

(ii) *Biomass Support Particles*
These particles allow high biomass concentrations in continuous fermenters and have provided the basis for biomass recovery based on decantation and compression as an alternative to sedimentation, filtration, centrifugation, etc.

(iii) *Whirlpool Separator*
This separator allows the batch processing of brewers' wort and produces a clarified liquor and concentrated slurry. The vortex principle established by Einstein describes the operation of the separator but the phenomena involved are those commonly experienced in the deposition of tea leaves following stirring.

(iv) *Enhanced Liquid-Liquid Extraction*
Electrically enhanced extraction occurs when a dispersed phase is passed through a high voltage nozzle. This results in small droplets moving at high velocities, with high mass transfer coefficients, i.e. conditions appropriate to the separation of materials which are sensitive to prolonged exposure to either heat or solvents.

(v) *Cross-Flow Filtration*
Rigid porous membranes of appropriate structure allow the high rate passage of clarified liquor while excluding microorganisms, thus producing a concentrated slurry. Such filters can be organised in shell and tube and similar arrangements.

MATTERS FOR CONSIDERATION

The above remarks describe the situation where the difference between the possible selling price of the product and the cost of the raw materials used in its preparation is very small. This difference in cost defines the allowable cost of processing. Clearly under these circumstances the concern is with a high level of process engineering technology and the implications are that large scale biological process engineering requires an initial processing capability greatly in excess of that which has usually been necessary in the past when developing new processing areas.

The concern of the committee is clearly associated with the supporting infra-structure of biotechnology/biochemical engineering and I would suggest consideration be given to the following points:

(a) The need for promotion of teaching, research and assessment of large scale biological process engineering within the chemical process engineering of the Chemical Engineering Departments within the UK.

(b) How students grounded in biological sciences can be converted so as to make a contribution to large scale biological process engineering. The original observational origins of biological science and its evolution as a service or associated with health care are traditions which work strongly against this need.

(c) How research targetting can be promoted in the University/public research areas based upon the allowable cost of the various processing steps.

(d) How the balance of the total UK research capability in biochemical engineering/ biotechnology covering Universities, Government Research Establishments, for example ARC and MAFF funded, and Industrial Research Associations and Foundations can be assessed.

(e) How consideration of biotechnology as restricted to small scale, high value products can be avoided and areas of large scale activity can be included for consideration.

(f) The research support for equipment manufacturers and process engineering contractors should be viewed as equally important to that in support of laboratory scale biotechnology.

(g) The combination of skills, areas of knowledge, abilities, styles and motivations of those persons who currently make up the UK compliment of biotechnologists/ biochemical engineers should be assessed and the ways in which any necessary adjustments can be achieved should be identified.

APPENDIX 6

Memorandum Submitted by the Genetic Manipulation Advisory Group

BIOTECHNOLOGY (B 19)

Definition of Genetic Manipulation—as defined in the 1978 Genetic Manipulation Regulations:—

> "the formation of new combinations of heritable material by the isolation of nucleic acid molecules, produced by whatever means outside the cell, into any virus, bacterial plasmid, or other vector system so as to allow their incorporation into a host organism in which they do not naturally occur but in which they are capable of continued propogation".

It should be noted that the use of the "genetic manipulation" technique as described above, only represents a small contribution although an important one, to "biotechnology" research and its applications. Genetic manipulation as defined above does not include for example, strain improvement of micro-organisms by conventional genetic techniques, monoclonal antibody work, *in vitro* fertilization or cloning techniques for animal use.

THE GENETIC MANIPULATION ADVISORY GROUP (GMAG)

The GMAG was set up in 1976 and is the central advisory group comprising members appointed by the Secretary of State.[1] The terms of reference of GMAG are:—

[1]For Education & Science.

MEMORANDUM SUBMITTED BY THE
UNIVERSITY OF CAMBRIDGE, SCHOOL OF THE BIOLOGICAL SCIENCES

1. To advise:—
   (a) those undertaking activities in genetic manipulation, including activities related to animals and plants and;
   (b) others concerned.

2. To undertake a continuing assessment of risks and precautions (and in particular of any new methods of physical or biological containment) and of any newly developed techniques for genetic manipulation and to advise on appropriate action.

3. To maintain appropriate contacts with relevant government departments, the Health and Safety Executive and the Advisory Committee on Dangerous Pathogens.

4. To maintain records of containment facilities and of the qualifications of Biological Safety Officers.

5. To make available advice on general matters connected with the safety of genetic manipulation, including health monitoring and the training of staff.

CATEGORISATION OF LABORATORY EQUIPMENT

The GMAG introduced a risk assessment scheme for the categorisation of experiments (GMAG Note 14, attached). The scheme can be operated by Local Safety Committees and allows most work (about 80–90 per cent) to proceed under category I containment or under conditions of "good microbiological practice"—such work does not require GMAG's prior advice before it goes ahead. Only work in the higher containment categories (i.e. II to IV) requires GMAG's specific advice before it goes ahead.

"USE" OF GENETICALLY MANIPULATED ORGANISMS

The Group has recently revised its procedures for giving advice on the "use" of genetically manipulated organisms (GMAG Note 12 (revised), attached). Large-scale or industrial work involves the "use" of the manipulated organisms rather than genetic manipulation *per se*. The Group restricts its advice to the biological aspects of the work—the HSE advises on the physical aspects.

COMMERCIAL PROPOSALS

The importance of the industrial use of genetically manipulated organisms is fully recognised by the Group and it has maintained a policy of giving every encouragement to such work—consistent with goods manufacturing practices.

CENTRES INVOLVED IN GENETIC MANIPULATION

There are now 103 centres registered with GMAG for genetic manipulation work and 5 centres have sought advice on the large scale "use" of genetically manipulated organisms.

APPENDIX 7

Memorandum Submitted by the University of Cambridge,
School of the Biological Sciences

BIOTECHNOLOGY IN THE UK: TRAINING, RESEARCH AND INDUSTRIAL APPLICATION (B 20)

1. The importance of the Cambridge contribution to molecular biology and hence to biotechnology needs no lengthy exposition—it has been absolutely fundamental to the development of the subject as we know it today. If, however, we are to exploit to the full the pure science which has been done here and elsewhere in Britain in the last thirty years in this field, there has to be a deliberate effort in both training and research to transform

Memorandum Submitted by the University of Cambridge, School of the Biological Sciences

the basic science into industrial output. The Cambridge group (biologists and chemical engineers) which has been considering this matter since the publication of the Spinks Report see two ways in which the academic support for such an effort can be mounted:—

(i) by training a cadre of high quality graduates from both the physical and the biological sciences in the concepts and techniques relevant to biotechnology as they are applicable to industry. The aim should be to introduce each side to what they need to know of the other's discipline, to understand one another's "languages", and to lay firm bases for co-operation on the kind of hybrid project which characterises biotechnology. Training of this kind must be at post-graduate level. Biotechnology is not an under-graduate subject.

(ii) by providing the right kind of environment in which such training can best be done. The kind of training needed has to be intellectually demanding and stimulating but at the same time practically orientated—with plenty of "hands-on" experience and simulated industrial/commercial exercises. Recent experience in Cambridge strongly suggests that at this stage in the development of biotechnology here there is a gap to be filled between the fundamental research which is done in university departments and research institutes and the full development of these ideas to industrial scale; and a need for some of the first-rate biologists who originate the basic biotechnological techniques to think in terms of applying their know-how in the industrial field, in much the same way as in recent years computer graduates have started their own successful companies. A kind of "half-way house" is needed between pure research and industrial application, which would best be provided by a strong academic unit closely linked to the fundamental disciplines of biotechnology on the one hand and to industry on the other.

2. Such a unit would provide the best atmosphere in which to train biotechnologists in the type of post-graduate course outlined in the first appendix to this note. It is an intensive one year course leading to an MPhil degree and designed to turn out 15–20 high quality graduates a year. It would need a permanent staff of a Director (at professional level) and three lecturers but to provide the broadly-based teaching envisaged and to allow them time to develop first-class research the permanent staff would need to enlist the services of specialists from other related departments, research institutes and industry to take part in the teaching as well as in co-operative research. The course would run continuously from September to June (except for short breaks at Christmas and Easter), disregarding traditional University terms. There would be an emphasis on learning by doing. In many cases like molecular cloning of DNA the concepts are relatively straightforward, but to be a successful practitioner, an ability to work fast and economically in the laboratory is essential, and can only be learned at the bench. The course is aimed to encourage communication between students of widely different academic backgrounds, by involving them, in teams of about three, in projects which encourage them to learn from each other and get biologists, physical scientists and engineers into the way of talking easily to each other and understanding each other's problems and approaches. The formal teaching would be supplemented by regular visits to industrial laboratories and plants. The course could be so structured as to provide modules which could stand on their own as short courses attractive to scientists from industry wishing to up-date their knowledge. The kind of scientific community in which a development of the type outlined here could flourish best is exemplified by the cluster of scientific institutions (University and Research Council) in and about Cambridge. The second appendix attached to this paper gives some idea of the variety of these institutions and their interests.

3. The position of biotechnology today has some similarities with that of chemical engineering immediately after the war. Then there were differences of opinion in industry about the need for such a breed as chemical engineers. Some parts of the chemical industry thought that all that was needed were physical chemists produced in conventional chemistry departments combined with mechanical engineers, but the petroleum industry knew differently and Shell had the vision to endow a Department and Professorship of

Chemical Engineering in Cambridge. It is perhaps too much to ask, in these days of severe recession, for another such bold and imaginative stroke from one company but is it too much to expect that Government and industry acting together should have enough foresight to provide for the continuing supply of biotechnologists which will be needed if the new technology is to feature in Britain's future on a scale commensurate with the contribution which British fundamental science has made to the foundations of the industry? The Government money need not all be UGC money. The Department of Industry has a brief to encourage industrial innovation and support it financially: it should not interpret that role too narrowly but should be prepared to put money into relevant educational (teaching as well as research) projects of the kind described here as well as into research and development in industrial laboratories and plants. The money from industry need not all come from companies in manufacturing and processing. We notice that pension funds, banks and insurance companies are finding venture capital for biotechnological projects: they would be wise to put some of their money into educational efforts designed to ensure that the firms they are supporting will, when they reach maturity, have a good supply of first-rate graduates conversant with the science and engineering on which their businesses depend. Until the Universities have emerged from the painful period of retrenchment and re-adjustment to which they are being currently subjected they are unlikely to be able to add, to any significant extent, from their present resources to the effort they are already devoting to biotechnology and related subjects. However, the number of centres in the UK with the right concentration of biological and chemical engineering expertise needed to mount the kind of effort described in this paper is limited. If the UGC has any money to put to the development in biotechnology in the universities they must discriminate heavily in favour of these centres both in terms of "earmarked" development funds and in their contribution to the dual support system, which is in an almost terminally weak state at present. A policy of "earmarking" over a period longer than the usual five years or less is urgently needed to give universities, in these particularly difficult times for them the confidence to embark on long-term developments.

4. In conclusion there are two points we wish to make emphatically:

(i) any money provided by Government for the development of the applied aspects of biotechnology must not be provided at the expense of basic research.

(ii) the Government should not restrict its search for advice on questions affecting the development of biotechnology and the training of biotechnologists to conventional sources. The orthodoxies which these often represent are not likely to offer the most valuable guides to the future course of events in biotechnology. It seems particularly dangerous, in the case of biotechnology, to channel advice through a small number of official organisations. Much better to consult widely and ensure that the advice received is not interpreted on preconceived lines before it reaches the point of decision.

21 May 1982

APPENDIX I

Proposed MPhil in Biotechnology

A: INTRODUCTION

1. The aim of this course is to provide intensive training in biology as it applies to commercial applications. Students from both the biological and physical sciences will take common laboratory and lecture courses that will introduce them to the theory and practice of biotechnology; with especial emphasis on the application of molecular biological techniques to changing the characteristics of organisms to meet particular requirements. The laboratory courses will be designed with the aim of giving the students first hand experience in a range of techniques and introducing them to some of this technology. The lecture courses, with associated seminars and visits to commercial firms, will have the following aims:

Appendix I to the Memorandum Submitted by the University of Cambridge, School of the Biological Sciences

(i) To provide the necessary biological background to those whose previous training has been in engineering or a physical science and the necessary engineering background to the biologists, as well as providing more advanced training. It is intended that those taking the course would be able to appreciate the range of questions thrown up by biotechnology and be able to discuss these with experts in branches of the subject not their own, rather than that all students should reach the same standard in all parts of the course.

(ii) To lead to a detailed understanding of the basic principles that underlie the laboratory work.

(iii) To instil an appreciation of the differences between laboratory scale experiments and industrial procedures.

(iv) To gain a realisation of the variety and scope of existing and planned activity in this area.

(v) To appreciate the economic aspects of potential biotechnological projects.

2. We envisage a ten month course beginning in September and running through until the end of the following June. We see the course accommodating about 15 students a year and would hope that there would be a reasonable balance between those with first degrees in the biological and physical sciences, particularly in chemical engineering. A 2.1 degree would normally be the minimum standard for entry (see Annex).

3. The course will be designed for graduates of proven ability, who wish to extend and broaden their training. As far as possible it will be modelled on the successful scientific summer schools which have become prominent in recent years, e.g. the Cold Harbour Spring Laboratory Summer course. The pace will be pitched at a level appropriate for selected students who have successfully completed a demanding first degree course. They will be expected to be highly motivated and follow an intensive programme of lectures/discussions and laboratory work and be ready to acquire unfamiliar ideas from other disciplines. For the physical scientists these will comprise concepts in biochemistry and molecular biology: for biologists, they will include appreciation of the quantitative approach which plays a central role in the physical sciences and engineering. The range and intensity of the course will be such that it cannot all be provided by the three or four full-time teachers concerned. We believe a solution to this is to invite experts on specific topics from universities and research institutes to teach segments of the course over periods from one to three weeks. Industrial lecturers would probably prefer to come less frequently (a day a week) for more extended periods. If this scheme is to work suitable arrangements must be made to pay such people a reasonable fee and to attract them to Cambridge by, for example, the high quality of the students, staff and support facilities. The full time staff will, of course, teach those areas of their particular expertise and provide overall continuity and direction.

4. A most important aspect of the course is to encourage close working relations with relevant industrial concerns, at both the research and production levels. This can be done in several ways. We would hope that "site visits" would occur, perhaps every two weeks to allow the students to get a real idea of what actually goes on in industry and allow them to meet potential employers, and *vice versa.*

5. It is also important that the staff of the course are sensitive to the changing needs of industry. Indeed, we would hope that at least one staff member would come with some considerable experience in industry. In addition to the fostering of industrial contact that will occur through site visits, contract research by staff members would be encouraged. An important part of the course will be the practical and design projects in the Lent and Easter terms (see below). Although it would not be realistic, or even desirable, for the students to carry out contract research during this time we would like to encourage industry to come forward with suggestions for such projects.

6. Attendance at the course by scientists from industry would be encouraged. In view of the difficulty industrial scientists might have in taking a whole year from their normal

work to study we would structure the course in such a way that industrial scientists could come to Cambridge for a limited period to attend one (or more) course "modules". The possibilities of holding special short courses for industrial scientists and arranging intensive specialist training would be investigated.

7. We presume that relationships between the course and industry will have to be carefully nurtured until such times as the "two parties" gain mutual confidence and awareness of how they can help each other.

B: THE CURRICULUM

SEPTEMBER

8. During the first month resident staff will concentrate on providing introductory courses designed to give necessary background to students from different disciplines. Lectures on these background topics together with example classes will continue through the academic year as required. Two such courses will be given.

(i) To equip physical scientists and chemical engineers with the necessary biology.

(ii) To teach biologists relevant fluid mechanics and chemical engineering.

Some indication of the scope of these courses is set out in the Appendix.

MICHAELMAS TERM

9. From October to December there will be two major courses: (a) biological and (b) technological, for all students (two lectures a day plus practicals).

(a) *Biological*

10. This will provide the students with a wide range of experience in the practice of microbiology, biochemistry and molecular biology. It will be problem-solving in orientation and will, as far as is possible, keep practical applications in the foreground, without neglecting the fundamental theory. It is the aim to produce people with imagination, common sense and initiative who have had first hand experience of solving problems in the manipulation of micro-organisms. We suggest a course of 40 lectures (1/day) with associated laboratory work. A possible outline is:

Classical microbiology (10 lectures)
The isolation, growth and characterisation of bacteria.
Genetics—isolation and characterisation and mapping of mutants.
Bacterial viruses and plasmids.
Bacterial metabolism.
Yeast and their genetics.
Large scale culture; fermentation; the chemostat.
Isolation of products from the culture medium and from the organisms.

Enzymology (10 lectures)
Purification of enzymes from microbial cultures. Techniques for increasing yields; techniques for disrupting micro-organisms.
Assay and properties of enzymes.
Use of enzymes as tools, with special emphasis on the enzymes of nucleic acid metabolism (for example, students might grow up relatively large amounts of a variety of bacteria which make restriction endonucleases and purify these enzymes for use later in the course. Attention to yield and quality would be most important, and the students would gain experience of a wide range of different bacteria and an equally wide range of purification techniques and assays).
Attachment of enzymes in inert supporting media, and use of such preparations in catalysis.

Appendix I to the Memorandum Submitted by the University of Cambridge, School of the Biological Sciences

Recombinant DNA technology (10 lectures)
Isolation and assay of messenger RNA. Construction of cDNA libraries and identification of the desired clone. Use of cloned DNA in analysis of the genome. Construction of genomic libraries; comparison of different vectors. Cloning in yeast. Assaying for expression of cloned sequences in *E. coli* and yeast. Maximising expression and methods for obtaining secretion of products.

Mammalian cell culture (10 lectures)
Growth of mammalian cells. Viruses and how to assay them. Cell fusion and monoclonal antibody production. Production of antisera. Cloning viral antigens in bacteria for antigen production.

It is obvious that these topics could easily take up a whole year, depending on the breadth and depth of their coverage. We envisage a course which resembles an advanced workshop; we would expect students and teachers alike to spend long hours in the laboratory. We would also expect the members of the course to be self-reliant to a considerable degree.

(b) *Technological*

11. This will provide the students with a quantitative appreciation of the theory and practice of chemical engineering as relevant to biotechnology applications. It will, in particular, be concerned with the unit operations used in the manufacture, separation and purification of the productions of biotechnology. In order to achieve this, substantial effort will have to be directed to providing an analytical and quantitative background of fluid mechanics and transport processes. In addition, the importance of appreciating at an early stage the economic and engineering problems of scaling up a process will be stressed. Such topics, although they need not involve advanced physical concepts, do require some familiarity with mathematical manipulation. For this reason we consider an A-level in mathematics, or its equivalent, essential for those taking the course. The technological component will also be of 40 lectures (1/day) throughout the Michaelmas Term. Relevant topics are:

Biokinetics, reactors

(i) *Kinetics and yield* in cell cultures
Growth parameters. Phase of batch culture. Monod equation and substrate utilisation. Enzyme kinetics.
The ideal CSTR fermenter. The Monad chemostat and its variations. Washout behaviour. Chemostats in series.
Batch and plug flow cultures and the application of the Monod equation. Product synthesis in a batch culture.

(ii) *Heat and mass transfer* in biological reactors
O_2 requirements of a culture, gas-liquid mass transfer. Measurement of mass transfer co-efficients. Aeration and agitation power requirements to achieve specified k_La, scale-up.
Transfer of growth limiting substrate to cells, pellets, microbial films, supported enzymes.
Packed towers and biomass film reactors.
Bubble column fermenters.
Instrumentation.
Computer control of fermentation to optimise product yields.

Isolation and use of bioproducts
Product recovery. Precipitation; salting-out kinetics, isoelectric precipitation, variation of solvent dielectric constant, action of non-ionic polymers. Coagulation.

Lent/Easter Term

12. During the period January to June we see the bulk of the student's time being devoted to project work. In addition, however, more formal teaching will continue:

APPENDIX I TO THE MEMORANDUM SUBMITTED BY THE UNIVERSITY OF CAMBRIDGE, SCHOOL OF THE BIOLOGICAL SCIENCES

(i) *Advanced seminar series*

We suggest two advanced seminar series, one to be in chemical engineering, the other to be in molecular biology. These will allow certain subjects to be considered at a higher level than would have been possible earlier. Any one student would opt for only one of these series, according to his inclinations.

(ii) *Case studies*

With the view of introducing students to the intellectual and practical breadth of biotechnology we suggest a series of detailed "case studies", each topic to be taught for one week by lectures and associated reading, discussions and visits. These "case studies" would be taught from both the theoretical and practical points of view and would, often, require outside teachers. Possible topics are:

The production of human peptide hormones by cloning in bacteria.
The production of antibiotics.
The design and use of automated analytical systems.
Fermentation processes in the food and drink industries.
Industrial chemicals from fermentation.
Vaccine production.
Micro-organisms and waste management.
Micro-organisms and metal ore processing.
Industrial applications of plant cell culture.
Novel techniques in plant breeding.

(iii) *Projects*

It is very important that students gain experience in seeing through particular problems. Towards the end of the Michaelmas Term we see the students discussing potential projects with the staff and amongst themselves, and then forming small teams, of two to four students, who will get together and collaboratively carry out a suitable project. Ideally each team will consist of at least one biologist and one chemical engineer and they will consider their project from both the theoretical and practical points of view, with the aim of producing a well-documented report at the end of the course. The projects should, in principle at least, have a heavy practical/commercial orientation and the students would be required to consider all the factors (including economic factors, market forces, etc) relevant to industrial scale production.

(iv) *Design*

In parallel with the research (i.e. practical) project the students, again working as small teams, would be required to conduct a theoretical design, so that they would gain some experience and appreciation of the important and difficult problems in moving from the laboratory bench to production. A typical example might be the development of a process for a new antibiotic. Questions which would have to be considered would be:

A flow sheet for the process.
The quantities and costs of the materials required, e.g. at what point could one assume starting materials were commercially available or had to be manufactured on the site.
The design of various units such as fermenters, equipment for flocculation, distillation, crystallisation, charcoal bed adsorbents, etc.
Plant control.
Environmental and biohazards.
Major requirements, costs for utilities, etc.
Production costs, market assessment and profitability.

13. It is to be emphasised that the design project is not envisaged to include practical work on a pilot scale: experience in the Chemical Engineering Tripos amply demonstrates the value of conducting a preliminary design exercise and emphasises a "systems approach", i.e. to develop an awareness of the system as a whole, rather than its component

APPENDIX I TO THE MEMORANDUM SUBMITTED BY THE
UNIVERSITY OF CAMBRIDGE, SCHOOL OF THE BIOLOGICAL SCIENCES

parts in isolation. A further feature of process design is that, almost invariably, a large number of physical parameters and properties are unknown and have to be estimated from the literature, from correlation and from experience. The research emphasis of this course would make it desirable that students, in any report, should specify a programme of research intended to answer problems that have been uncovered during the design project.

14. Questions of the role of management and economics will be introduced and discussed in the technological part of the course and in the context of the case studies and projects described above.

C: STAFF AND OTHER RESOURCES

15. It will be clear from the outline given above that the course described could not be provided using existing University facilities and staff only, especially when these resources are increasingly under strain to meet current commitments. The intensive nature of the course, its practical orientation and its close associations with industry will require that the main responsibility for organising and teaching should be given to a full time academic staff, specially selected for the task not only with teaching and administrative abilities in mind but also with regard to potential for advancing the subject by research. To satisfy these demands an academic staff of four would probably be required (a Director and three other teaching officers). The final choice of individual staff would have to await the appointment of a Director, but it is envisaged that the choice of staff would reflect the main disciplines involved and would include at least one chemical engineer. Substantial contributions made to the teaching of the course by existing departments would be balanced by reciprocal contributions to departmental teaching by the Director and his staff.

16. The extent of the back-up required for the academic staff will depend to some extent on their interests and the help which can be obtained from existing facilities, but it seems likely that there will be a need for a secretary to serve the group and four technical assistants, one with workshop experience.

17. The aims of the course are most likely to be fulfilled if the responsibility for achieving them is given to an enthusiastic team in full control of the resources allocated for the purpose. About 600 m^2 net of accommodation would be ideal but that may not be available at the outset. The minimum which a unit of the kind envisaged would require is a teaching laboratory, research space (including a computer facility) for the staff, a seminar room and a reading room for specialised periodicals. The relationship to existing departments remains to be determined; nevertheless, exclusive use of the minimum accommodation listed above would be indispensable. The laboratories would have to be extensively equipped to handle a very diverse range of techniques. In addition to the normal equipment of a well-found molecular biology/biochemistry laboratory it would require facilities for tissue culture, fermentation and product separation.

18. The proposed unit could best achieve its aims if it had a certain degree of autonomy. The Director should be responsible initially to an informal Committee of Management comprising representatives of Biology "A", Biology"B" and the Chemical Engineering Syndicate and the Appointments Committee established to appoint the academic staff would be constituted in accordance or by analogy with the regulations for Appointments Committees for offices having responsibilities in more than one Faculty or Department (Statute XVII, 5.) All the facilities and resources required would have to be treated as new needs, so that no existing department contributing to the venture is obliged to divert resources to support the new course. It is therefore proposed that all the money needed be obtained by an appeal to industry, charitable foundations, research councils, government sources and the EEC.

29 January 1982

APPENDIX II TO THE MEMORANDUM SUBMITTED BY THE UNIVERSITY OF CAMBRIDGE, SCHOOL OF THE BIOLOGICAL SCIENCES

ANNEX

(a) *Course Entrance Requirements*

Applicants should normally possess a first or upper second class honours degree in a physical or biological science, engineering or chemical engineering. If their university course has not included some mathematics they should have obtained an A-level in mathematics, or its equivalent.

(b) *Introductory Lectures*

(i) *For biologists*

Dimensional analysis, mass and energy balances. Lever rule.
Pressure drops and losses in pipes.
Settling of solids, flow through packed beds, filtration.
Centrifuges.
Heat-transfer, boiling, evaporation, heat exchanger design.
Drying.
Mass transfer, film theories, gas absorption and desorption, distillation and solvent extraction.
Basic chemical reactor theory, residence time distributions.

(ii) *For engineers and physical scientists*

Molecular genetics, the nature of the genetic material.
Introductory biochemistry, nucleic acids, proteins, carbohydrates, lipids.
Intermediary metabolism, cell energetics.
Cell structure.

APPENDIX II

BIOTECHNOLOGY IN CAMBRIDGE

Some idea of the range of existing relevant expertise and work already in the University and other research centres in Cambridge may be derived from the following brief summary.

Recombinant DNA technology

Many groups are now using these techniques for studying a wide range of problems. In the analysis of plant and animal viral genomes, work is being carried out in MRC Molecular Biology on tobacco mosaic virus and Epstein Barr virus and in Pathology on herpes simplex virus and fowl pest virus. In the analysis of genomes of micro-organisms, work is going on in Biochemistry on transport systems and on antibiotic production, in Genetics on gene regulation in fungi, in Pathology on schistosomes and in Parasitology on trypanosomes. Similar analysis in higher plants and animals includes the study of chloroplasts and lectin genes in Botany, *Drosophila* and tsetse fly in Genetics and human complement genes and nematode genes in MRC Molecular Biology.

MRC Molecular Biology
Biochemistry
Botany
Genetics
Pathology
Parasitology

APPENDIX II TO THE MEMORANDUM SUBMITTED BY THE UNIVERSITY OF CAMBRIDGE, SCHOOL OF THE BIOLOGICAL SCIENCES

Monoclonal antibodies

This technique was invented in Cambridge and, not surprisingly, many groups have long experience in making and using these important new tools in applications ranging from their clinical use to bulk purification of proteins. Chemical Engineering are investigating the use of immunoadsorbants made from monoclonal antibodies for large scale purification systems in the manufacture of such compounds as insulin, human growth hormone, interferons and vaccines.

MRC Molecular Biology
ARC Animal Physiology
Pathology
Chemical Engineering

Reproductive physiology

The techniques of *in vitro* fertilization of mammalian eggs were pioneered in Physiology and the ARC Unit of Animal Reproduction; in addition, nuclear transplantation techniques have been exploited by Gurdon and his colleagues in MRC Molecular Biology. A small group in Anatomy is studying early mammalian development, and there are several groups working on cryogenic preservation of living cells (Zoology, NERC Culture Centre).

ARC Animal Physiology
Physiology
MRC Molecular Biology
Anatomy
Zoology
NERC Culture Centre for Algae and Protozoa

Applied microbiology and microbial genetics

In Chemical Engineering techniques are being developed for downstream processing of biological products, and the competition and growth dynamics of organisms in fermentation processes are being studied. Several groups in Biochemistry work on bacteria and their genetics; for example, on bacteria spores, on the mechanism and genetics of sugar uptake systems and on the mode of action of antibiotics.

Members of Biochemistry give lectures on microbial metabolism and growth to Chemical Engineering students. Work is also being carried out in MRC Molecular Biology on the purple photosynthetic bacteria and on yeast mating types.

Chemical Engineering
Biochemistry
MRC Molecular Biology

Plant biology

A considerable effort in the use of recombinant DNA techniques as applied to analysis of plant genomes is going on in the Plant Breeding Institute and, increasingly, in Botany and Biochemistry. Plant cell culture is widely employed in research in these departments. It is still the case that most of the recent notable increases in wheat yield, for example, have arisen from the application of traditional applied genetics, and the Plant Breeding Institute is outstanding in this field.

Plant Breeding Institute
Botany
Biochemistry

Pharmacology

The MRC Molecular Pharmacology Laboratory is particularly strong in the study of neuro-transmitters, and generally in the study of brain biochemistry. The University Department of Pharmacology has close contacts with the pharmaceutical industry and is engaged in research on anti-tumour drugs.

MRC Molecular Pharmacology
Department of Pharmacology

Fermenter technology	
Extensive studies have been made on air-lift fermenters including a unit 10 m high. The factors governing the rate of absorption of oxygen, the rate of liquid circulation, the intensity of mixing, and the bubble size distribution, have been examined. These hydrodynamic and mass transfer effects are now being related to the behaviour of continuously operating fermenters using a variety of cultures. The results are important in scaling up from small bench fermenters to pilot plant and full-scale units.	Chemical Engineering

APPENDIX 8

Memorandum Submitted by the Confederation of British Industry

THE RESEARCH BASE FOR BIOTECHNOLOGY (B 21)

A memorandum to the House of Commons Select Committee on Education, Science and Arts from a joint working group of the Association of the British Pharmaceutical Industry and the Confederation of British Industry.

THE IMPORTANCE OF BIOTECHNOLOGY

1. Britain's economic growth is vitally dependent on its share of world trade. Technology has a significant role to play in strengthening and sustaining that share through:

- developing new products, processes and services with improved performance and higher added value;
- improving productivity;
- improving the quality of existing goods.

Competition in international markets is so vigorous that the UK cannot afford to ignore developments and opportunities arising from advancing technology. The pharmaceutical industry at present is making a significant contribution to the balance of payments through its exports. The strength of UK research is an important factor in this; the development of biotechnology in the UK is therefore a major interest for the future.

2. Biotechnology is important for two reasons:

- it is a "heartland" technology with a range of possible applications which could ultimately affect many other branches of technology and industry;
- the UK has already established a leading position in a number of the disciplines which contribute to the subject.

3. The policies adopted towards research and development in biotechnology will therefore have a major impact, not only in the shorter term by affecting the rate at which the UK can follow up and exploit opportunities already evident, but also in the longer term by defining the knowledge base in academia and in industry which will support future developments in this important technology.

4. The ABPI and the CBI therefore welcome this enquiry into biotechnology in the UK. Our present paper focuses on the research base and the need to strengthen it. Earlier evidence submitted in 1979 to the House of Commons Select Committee on Science and Technology dealt primarily with the industrial opportunities arising from recombinant DNA technology and the regulatory environment affecting its development; similar evidence was also submitted to the joint working party of the Advisory Council for Applied Research and Development, the Advisory Board for the Research Councils and the Royal Society. In 1981, ABPI and CBI members also contributed to the Royal Society study on Biotechnology and Education.

Memorandum Submitted by the Confederation of British Industry

The Need for Fundamental Research

5. The importance of fundamental research is well illustrated by genetic manipulation work. Much of the UK's present expertise in the technology evolved from work carried out some 30 years ago by scientists working in London and Cambridge, with grants from the Medical Research Council, on the structure of the genetic material, DNA. Work such as this has given the UK a strong international position based on the skills and achievements of its academic and industrial biological scientists. However, if the UK is to benefit from biotechnology, these past achievements must be developed further and an adequate supply of skills must continue to be available.

6. We therefore support the recommendation made in the ACARD/ABRC/Royal Society report on Biotechnology that adequate research facilities should be built up in universities based on the expansion of a limited number of centres of excellence in biotechnology from amongst the best existing in the field. These centres of excellence should be strengthened and financed adequately both with short-term injections of funding and longer-term assurance of funding, so as to provide a sound research and teaching base. Currently, universities and other academic centres are under considerable pressure to cut their budgets; it is essential that centres of excellence clearly producing good fundamental research in biotechnology should be identified and safeguarded from such cuts. It is essential that industry be consulted on the ways in which cuts in university expenditure are to be applied, so as to prevent damage to valuable research centres.

Co-ordination of Research Effort

7. Co-ordination between the Research Councils and the University Grants Committee was also called for in the ACARD/ABRC/Royal Society report on Biotechnology. We are aware that an Inter-Research Council Co-ordinating Committee on Biotechnology has been set up to co-ordinate programmes, to rationalise them where necessary, and to identify areas where new work should be commenced which have not been adequately covered by existing research. We therefore hope that an early start can be made on identifying and strengthening our academic centres of excellence in order that our national resources can be deployed to maximum effect in this rapidly advancing technology.

8. We welcome the recent announcement that the Government has set up an interdepartmental committee, under the chairmanship of the Government Chemist, to provide a focus for biotechnology. As was pointed out in the CBI's recent evidence to the House of Lords Select Committee on Science and Technology for their enquiry into Science and Government, liaison between government departments and other bodies, such as ACARD, the British Technology Group and the Research Councils, is essential to prevent unnecessary duplication in research and development programmes and to ensure that any important gaps are detected. Such liaison is particularly necessary where technologies have possible applications spanning a wide range of industries; biotechnology, microelectronics and information technology are obvious examples. Again we stress that biotechnology is developing rapidly and early consultations with industry are needed to define areas of work which need to be carried out.

Skills Supply

9. There is a shortage of adequately trained staff in the various disciplines which constitute biotechnology. It should be recognised that biotechnology is not a specialism in itself, and that a range of other disciplines (i.e. chemical engineering, microbiology, biochemistry, genetics, molecular biology and fermentation technology) are all involved; this needs to be taken into account when considering educational requirements. Other countries are providing greatly enhanced facilities for learning in disciplines associated with biotechnology. Attention should be given to strengthening teaching in these disciplines, and ensuring that the grant system is adequate to support the necessary students.

Memorandum Submitted by the Confederation of British Industry

10. A further concern is the need for adequate training of technical staff as there is a shortage of technicians with knowledge of the techniques employed in biotechnology. Urgent attention should be given to establishing sound academic facilities to train such staff.

Academia/Industry Liaison

11. Industry is seriously concerned that there should be appropriate arrangements for commercial exploitation of the findings of the centres providing the fundamental research base. Academic centres do not always have the necessary commercial expertise to identify the potential of their discoveries at an early stage, although it must be recognised that some universities have set up contract research units and the best of these do indeed take a thoroughly practical and commercial approach to industrial collaboration. Particularly in biotechnology it is crucial that a primarily academic group should have access to advice and support on the patenting and licensing of their findings. Of course the British Technology Group offers such a service, but this could usefully be complemented by business offices in the academic centres of excellence which would have the responsibility for identifying the potential of discoveries, making appropriate arrangements for their protection and exploiting them in the most flexible way. An interface of this type between the academic and business worlds would facilitate commercialisation of fundamental research in a way which would enable the return from licensing or other agreements to be channelled back into the research centre thus strengthening it further.

12. Links between academic institutions and industry can be established by a number of means ranging from the Science and Engineering Research Council's Co-operative Awards for Science and Engineering through to contract research projects. Difficulties do exist in forging close links where the academic institution is not prepared to accept the need for the confidentiality necessary for industrial developments such as biotechnology. New findings cannot always be protected by patenting and some accommodation is necessary between the academic emphasis on publication and the industrial need for confidentiality.

Conclusions

13. The Government has begun to take steps which respond to some of the recommendations in the ACARD/ARBC/Royal Society report on biotechnology, but we would emphasise the importance of a firm commitment to strengthening the academic research base through centres of excellence, and developing ways for the best possible transfer of the resulting fundamental research into industry.

May 1982

References

(a) Second Report from the Select Committee on Science and Technology, Session 1978–79, "Recombinant DNA Research—Interim Report", (HMSO) pages 195–205 and 217–226.

(b) "Biotechnology", report of a Joint Working Party (ACARD, ABRC and Royal Society), (HMSO: ISBN 0 11 630816 8), March 1980.

(c) "Biotechnology and Education", report of a Working Group, Royal Society, November 1981.

APPENDIX 9

Memorandum Submitted by The Royal Society

BIOTECHNOLOGY (B 22)

INTRODUCTION

1. In 1978 the Society's Officers were approached by the then Deputy Chairman of the Advisory Council for Applied Research and Development (ACARD), the late Dr A. Spinks, F.R.S., about a possible joint study on biotechnology. A Working Party established by ACARD, the Royal Society and the Advisory Board for the Research Councils (ABRC) produced its report, commonly known as the Spinks Report, in March 1980.

2. The Government responded in March 1981 by issuing a White Paper (Cmnd. 8177). In common with many others the Society was gravely disturbed by the absence of urgency or positive commitment. (The response by the Council of the Royal Society to the White Paper, which was forwarded to relevant Ministers in June 1981, is at Annex A.)

3. The ways in which the Society responded to the Spinks Report are detailed in Annex A. The report of the Society's Working Group on Biotechnology and Education was published in November 1981. A summary, including recommendations on schools, further and higher education and post-experience education and training for biotechnology, is at Annex B. The Society, together with the Science and Engineering Research Council (SERC) held discussions in September 1981 in Tokyo with the Japanese Ministry of Education and Science (Mombusho) on Anglo-Japanese collaborative research in biotechnology. In April 1982 a joint Royal Society/SERC group visited universities, institutes and companies in Japan. At home, the Society is appointing an additional Senior Research Fellow in the biological sciences and a Junior Fellow in a subject underpinning biotechnology. Further discussion meetings have been arranged.

4. Informal discussions in late autumn 1981 between certain members of Council, the Deputy Executive Secretary and others and members of the Select Committee led to an invitation from the Chairman for a statement on the future of biotechnology in the universities. That informal and personal statement provided the background (see Minutes of Evidence) to the Society's oral evidence to the Committee on 24 March 1982.[1]

5. This written submission aims to up-date, emphasize and detail some of the key points already made. It seeks to identify some specific actions which the Society believes should be taken to provide the necessary infrastructure for future developments in biotechnology.

6. The evidence has been prepared by an *ad hoc* Group under the Chairmanship of Professor Patricia H. Clarke (Vice-President of the Society), the other members being: Sir David Phillips, Sec.R.S.; Sir Arnold Burgen, For. Sec.R.S.; Professor B. S. Hartley, F.R.S.; Professor A. W. Johnson, F.R.S. (Members of Council); Professor J. F. Davidson, F.R.S. (Member of the Spinks Working Party) and Dr D. Rees, F.R.S.

THE CURRENT SITUATION

7. Since the Spinks Report was published ample evidence of the practicality of many of the proposed applications of biotechnology has emerged. Recombinant DNA techniques have been applied to the production of hormones and vaccines and to many diagnostic techniques; there are now good prospects for applications of cell fusion and vegetative cloning in agriculture, and many examples in industry of successful exploitation of new production methods for biological materials, albeit relatively few as yet on a large scale. Industry, particularly industry abroad, has responded to the new opportunities; genetic engineers, fermentation technologists and protein chemists are in big demand and, in some cases, short supply. Venture capital, even for projects of medium-term potential, is becoming available. At the same time there is growing public interest and expectation and strong motivation in many young people reflected in first class applicants for post-graduate research or industrial employment.

[1]HC 289-i.

Memorandum Submitted by the Royal Society

8. Within the limits of declining real budgets, Research Councils have also responded favourably. The SERC initiative in creating a Biotechnology Directorate is particularly welcome. Against this, however, has to be set the present unprecedented squeeze on university finances. This has seriously reduced their ability to maintain pre-existing effort in biotechnology; to develop truly interdisciplinary initiatives; to formulate coherent strategies for biotechnology and to allocate resources to the new area to meet the demand for teaching posts, rebuilding and other capital investment. Currently central Government response to the Spinks Report remains subdued. That said, there have been recent initiatives by the University Grants Committee (UGC) and the Department of Industry and we return to these welcome developments later.

9. Finally, these changes in the period since the Spinks Report must be viewed against the substantial public and private sector investment by our competitors overseas, e.g. in France, Germany, Switzerland, Australia, Canada, the USA and Japan. In each the investment has been accompanied by clear, well-advertised Government strategies and an evident commitment to the new technology.

Government Policy

10. If the United Kingdom is to make the best use of its undoubted resources and progressively to build up an adequate infrastructure for a competitive biotechnology industry, there remains an urgent need for a coherent and concerted Government policy. This must define an overall strategy in support of biotechnology. It should embrace provision of adequate financial incentives and a plan to ensure the supply of enough qualified people. We welcome the recent announcement by the Minister of State for Information Technology and Industry, Mr Kenneth Baker M.P., of the establishment of an Interdepartmental Committee on Biotechnology under the chiarmanship of the Government Chemist, Dr R. F. Coleman. This implicit Ministerial interest and responsibility for biotechnology should go far to negate the present lack of apparent Government commitment and we look forward to the new focus for biotechnology helping in the development of an overall strategy. In that context, the Committee must be provided with scientific and technological advice at all stages in its deliberations and, to that end, we recommend the appointment, as full members, of independent scientists and engineers from academia, Research Councils and industry. The Society would welcome the opportunity, along with other bodies, to nominate representatives. With such a focus to advise a Minister responsible for new and high technologies we could look forward to adequate priority for that pump-priming, measured assistance across the broad field of biotechnology which is so essential to its increased exploitation and coherent long-term development. More particularly, we hope that the Government will, on the advice of the Coleman Committee, place contracts for medium and long-term projects with university centres of excellence (see para. 12).

Manpower Considerations

11. A key concern is the provision of significant numbers of scientists, engineers and technicians with the necessary qualifications. As noted above, recent financial strictures on universities and polytechnics have seriously impaired their ability to (a) train the next generation of biotechnologists; (b) maintain and increase basic research underpinning biotechnology, and (c) enhance links with, and transfer results to, UK industry. Many departments are having difficulty in maintaining standards of teaching and research. Moreover, the financial cuts have lowered morale and encouraged an increased brain-drain of the most active and innovative scientists and engineers to posts overseas. We are pleased to note that the SERC Directorate has recently commissioned a register of those now resident in the United States who might under different circumstances take posts in the UK. We look to the new Interdepartmental Committee to consider how best to generate that return flow.

12. We believe it essential to safeguard and develop the quality of university and polytechnic departments in the wide range of subjects from which present and future biotech-

nology derives. It is important to avoid too quick or complete a focus on specific applications. We welcome the recent initiative by the UGC in designating as the first three centres of excellence in biotechnology—University College London (UCL), University of Birmingham and University of Manchester Institute of Science and Technology (UMIST). We conclude that three institutions were chosen because of their activities in the biological areas of chemical engineering, their collaboration in research and teaching extending across the boundaries between departments of biological science and engineering, and their long standing commitment to industrial applications of the biological sciences. We also welcome the UGC's approach to nine other universities (Cambridge, Edinburgh/Heriot Watt, Glasgow/Strathclyde, Leeds, Leicester, London, Sheffield, Wales, Warwick) to which earmarked support may be given. We believe that UGC funding for biotechnology should be concentrated mainly in a relatively small number of university centres, but that these should not be the only places for new initiatives in pure and applied biological science or in process engineering. Moreover, it is now necessary to create substantially more than the 20 new posts proposed in the Spinks Report (and to give complementary support in the polytechnics) if momentum is to be maintained.

13. Among the criteria which universities might adopt in making their final choices on the allocation of ear-marked funds are the following (not all of which need apply in each case):

(i) Special expertise in either a pure or an applied science related to biotechnology. One centre might, for example, have a commitment to plant science and agriculture, another to molecular biology or biochemistry.

(ii) Evidence of close cooperation with industry (whether in teaching, technology transfer or research collaboration) or with Research Council institutes and other pubicly-funded research establishments, or both.

(iii) Willingness to embrace some clear commitments to specific applications.

(iv) Extent to which funds made available for qualified manpower and equipment will be matched by Research Council or other research grants and vice-versa.

14. Action by the UGC alone is not enough to ensure an adequate flow of qualified manpower into biotechnology. We would urge the SERC and other Councils to increase the quota of post-graduate training awards to meet university and industry needs. Furthermore, the UGC initiative will take time fully to mature and should be complemented by a much enhanced provision for top-up, conversion and post-experience course places for graduates, immediate post-doctorals and those already employed in industry, as the Society has already envisaged (*Biotechnology and Education,* para. 72). Postgraduate conversion courses, in particular, provide an economic, effective and rapid means of providing suitably trained personnel. We believe that the Department of Industry, as the sponsoring department for the biotechnology industries, should support such courses, in concert with the Department of Education and Science (DES), the SERC and the UGC.

Industry-University Relations

15. University staffs have evidenced their willingness, despite current difficulties, to develop mutually beneficial links with UK industry and the Society has done its best to foster that communication and the transfer of research results. We look forward to greater use of the Royal Society/SERC Industrial Fellowships scheme to those ends. But university/industry relations need to be still further improved, notably in the biological sciences. Among the options that should be considered by industry are an increase in industrial consultancies, particularly for younger scientists and engineers in biotechnology, and honorary appointments for industrial staff at universities. On the latter, we believe the Government should fund (perhaps in part) five Visiting Professorships and (for younger people) five Visiting Readerships to enable industrialists to spend up to one day a week in university departments seen to have a clear national role in biotechnology or the underpinning scientific subjects. The fund would be used to reimburse to industry the appropriate fraction of salary and to provide a sufficient (preferably generous) expense allowance

for travel and accommodation to facilitate the smooth functioning of visits to achieve the necessary level of quality and commitment. The positions should be filled competitively at two levels: first by universities applying to make such an appointment supported by a clear statement of the use to which they would put it; and second by filling each position from the widest possible field in industry, using advertisement as well as personal contacts to identify candidates. The Society, as part of its developing relations with UK industry and with the Confederation of British Industry (CBI) would be prepared to consider administering such a scheme and lending its name to the posts.

16. Another aspect of academic-industrial relations follows from (i) the success of Celltech in assisting the transfer of Medical Research Council (MRC) expertise into commercial products and (ii) the proposal for a new, high-technology company now being discussed between the Agricultural Research Council (ARC) and the British Technology Group (BTG) to perform a comparable role in agriculture. In certain limited fields, e.g. biosensers and specialised equipment, we believe that small companies could be established. onto whose boards academics would be invited so as to provide direct partnerships of commercial and financial know-how with expertise in new scientific and technological developments. It would be appropriate for Government directly to support such initiatives as part of its general policy of stimulating entrepreneurship in biotechnology.

17. Nothing in the above should, however, be taken to minimize the important role that large industrial concerns will play in the growth of biotechnology, including their involvement with fundamental research in universities. We welcome, for example, the establishment of a joint laboratory at Leicester by the University and ICI Corporate Laboratory and the further proposal to set up a research laboratory there sponsored by a consortium of four major industrial companies. But, to help develop a realistic framework against which targets can be formulated for long-term academic research, as well as to obtain early benefits from biotechnology on a national scale, it is necessary to give more encouragement to large companies. These alone have the knowledge and experience to identify viable products for mass markets and the marketing management and production resources for quick exploitation on a large scale. A limiting factor here is the initial business commitment which is inhibited by the risk and cost of capital investment in a climate of high interest rates. We recommend Government consideration of a scheme of capital grants (or possibly tax concessions) for projects approved after rigorous commercial and technical assessment. Government support might be linked, in appropriate cases, to the provision of CASE studentships; the secondment of academics; the willingness to develop local university contacts and, where practicable, share facilities, or other forms of enhanced academic-industrial collaboration as outlined in paragraphs 15-16.

NATIONAL FACILITIES

18. In response to the White Paper, we indicated to Government that fuller use could be made of the potential capabilities of the Centre for Applied Microbiology and Research (CAMR) in developing new biotechnology programmes in concert with private industry. Pilot plant facilities and collaborative programmes between CAMR, university and industrial staff could provide the means for pursuing research and development on new and promising, but not as yet commercial, applications of academic research and for developing new methodologies which would be of common interest to Government, academia and industry. Moreover, it would be appropriate to focus Government action on biotechnology awareness, information and advice through a group accommodated at a multi-customer research centre of the kind that CAMR could become. We would urge the Department of Industry to consider this proposal.

19. A second aspect lies in the provision of national facilities for certain essential elements of the infrastructure not readily attributable to single or main customers or contractors. Among such elements are the national culture collections. Their current use by industry represents some 20 per cent of customer demand. This will increase substantially as more gene banks become established and we are concerned that at present several of the

MEMORANDUM SUBMITTED BY THE ROYAL SOCIETY

individual collections are in financial difficulties. This may reflect current priorities of their host organizations or funding agencies or both, but it is against the national interest in terms of the growth of biotechnology. We are aware of current concern, both national and international, and the Society will itself be making representations on this topic to Government. We invite the Committee to identify in its report the need for Government to make a concerted effort accurately to identify existing and future collective interest and to establish an appropriate administrative and financial structure for culture collections, as an essential support for developments in biotechnology.

LEGISLATION

20. We have been pleased to note that the Government has been undertaking a study on the possible affects of safety and health legislation on the development of biotechnology. For any novel field of growth, existing regulatory constraints can provide a more than average impediment to research, process development or production whether for those in universities or in industry. We hope that details of the Government's study and of such conclusions and recommendations as may have been reached will be made public as soon as practicable, not least as a further reflection of its commitment to this field of wealth creation.

SUMMARY OF RECOMMENDATIONS

21. The Society welcomes recent initiatives by the SERC, the Department of Industry and the UGC, but remains concerned at the adequacy of the nation's overall response in the light of developments by our competitors overseas. Accordingly we recommend that:

(a) The Minister of State for Information Technology and Industry be assigned responsibility for biotechnology;

(b) Independent scientists and engineers from academia, Research Councils and industry be appointed to the new Interdepartmental Committee and that the Committee advise the Minister on an overall strategy for biotechnology;

(c) The Department of Industry should place contracts with university centres of excellence for medium to long term applied R & D projects;

(d) The Interdepartmental Committee should consider how best to attract back to the UK expatriate research scientists with biotechnological expertise;

(e) The UGC in future planning should ensure adequate support for subjects underpinning biotechnology;

(f) The Universities should strive to ensure that the prime objectives of the UGC initiatives are realised and built upon;

(g) The SERC and other Councils increase their quota of postgraduate training awards, including CASE studentships, and, together with the DI, the UGC and the DES ensure enhanced provision for top-up, conversion and post-experience course places. These should be focussed on the UGC centres of excellence;

(h) Industrial companies should increase consultancies for younger academic scientists and engineers and embrace, with the support of Government, a scheme of Visiting Professorships and Readerships;

(i) The Government should assist the development of small entrepreneurial companies in certain specialized fields in which academics can play a significant role, and should consider a scheme of capital grants for large companies for approved projects;

(j) Fuller use be made of the CAMR in concert with private industry and academia, notably for the provision of pilot plant facilities, the development of new technologies and the promotion of awareness of biotechnology;

ANNEX A TO THE MEMORANDUM SUBMITTED BY THE ROYAL SOCIETY

(k) The Select Committee press Government to establish machinery to secure the future of the national culture collections;

(l) The Government continue to ensure that safety legislation does not unnecessarily constrain the growth of the biotechnology industry and its wealth-creating capacity.

3 June 1982

ANNEX A

Response by the Council of the Royal Society to the Government's White Paper *"Biotechnology"* (Cmnd. 8177).

1. A report on biotechnology by a joint working party for A.C.A.R.D., A.B.R.C. and the Royal Society was published in March 1980. This report dealt extensively with opportunities in this rapidly developing field, and drew attention to defects and constraints in their realization in the United Kingdom. The Report made a series of recommendations which were addressed to the Government, to other institutions wholly or partially dependent on public funds such as the Universities, the Research Councils and the Royal Society, and also to private industry.

2. In March 1981 the Government responded to the Report and recommendations by issuing a White Paper (Cmnd. 8177). The Working Party has subsequently commented on the White Paper, and the Royal Society now makes the following additional observations on the Government's response. Before presenting these, however, it is appropriate to draw attention to the Society's own initiatives on biotechnology.

3. In June 1980 Council agreed to create a Senior Research Fellowship, tenable for five to seven years, specifically in Biotechnology, with preference given to applicants presenting proposals with an identifiably applied thrust. An appointment was made in March this year to Dr D. L. Pyle (Imperial College London) to undertake research into the fermentation of biomass to fuels and chemicals. The Society has also taken a lead in considering the implications, for secondary school, further and higher education, of the growth in biotechnology over the next thirty years in terms both of an adequate provsion of suitably trained manpower and a balanced appreciation of its role in industrial development and national well-being. A Working Group of the Society's Education Committee, appointed last July, will report shortly. It has been consulting widely amongst interested parties. The Society has been concerned to enhance the opportunities for greater exchange between industry and academia, not least in biotechnology, and established a joint scheme to this end with the Science and Engineering Research Council in 1980. An award will be made shortly to a polytechnic lecturer to spend a period in I.C.I. engaged on biotechnology. Those in biotechnology are also being encouraged to use the Society's various schemes for bringing top-class scientists to the United Kingdom to work in centres of excellence here, and for facilitating visits by United Kingdom scientists to such centres overseas. In the same vein the Society has, in the last two years, run several international discussion meetings on biotechnology. It is thus actively encouraging awareness of biotechnology, and providing support for those in the field.

4. Turning now to the White Paper, we note that the Government welcomes the Report and agrees that biotechnology will be of rapidly growing importance. One action supporting this statement of principle has been the encouragement of the initiative by the National Enterprise Board (N.E.B.) in the creation of a new biotechnology firm, Celltech. We also recognize some response following the Working Party's recommendation in favour of greater involvement by the Centre for Applied Microbiology and Research (C.A.M.R.) in

ANNEX A TO THE MEMORANDUM SUBMITTED BY THE ROYAL SOCIETY

new biotechnology programmes from private industry and from Government. The recently heralded fusion of the N.E.B. and the National Research Development Corporation (N.R.D.C.) will be judged by results but may offer new opportunities for future initiatives. If, however, the White Paper is intended as a general indication of support for biotechnology, we find it totally unconvincing.

5. The modest indications of a positive attitude serve only to underline the quite inadequate response it reflects to the challenge identified in the Report of the Working Party. Few of the recommendations which concern the Government have been accepted. Some elements of machinery, such as the urgently needed interdepartmental forum are, it is said, "being established", but with no indication of the terms of reference or public identification of the individuals to be concerned. Other recommendations involving the Research Councils, the universities and the U.G.C., where the Government, through the Department of Education and Science (D.E.S.), could take a lead, are simply left to these bodies themselves to do the best they can within existing resources. It is encouraging that despite this unhelpful attitude by Government and current severe financial constraints, the Research Councils and universities are attempting to promote biotechnology. The White Paper also includes some discouraging views and opinions on certain technical aspects which seem to be at variance with current thinking.

6. The Joint Working Party's own statement on the White Paper, explaining a similar disappointment and dealing in some detail with the Government response to its own proposals, has already been sent to Government. While its language is if anything unduly moderate, we fully endorse this statement. We will not repeat the analysis, but there are two aspects which we wish to stress.

7. First, successful commercial development of biotechnology (and other new growth areas) needs a change in attitude in the United Kingdom, not only by the Government itself, but in academic circles and in industry where barriers between industries and universities and between academic departments, such as engineering and biochemistry, are a major obstacle. Obviously this is a long-term problem, which needs new institutions and new interdisciplinary approaches to education beginning in the schools. But perhaps, most of all, it requires increased mobility between the academic and the commercial worlds. We wish to emphasise that this should be a concern of the Government which could be active and influential by selective use of even scarce resources.

8. The second point concerns fiscal policies. The White Paper stresses that the successful development of new concepts in biotechnology rests with industry and that the Government can only provide the appropriate environment. At least thirty small new companies have recently been set up in the U.S.A. (compared to one in the United Kingdom). Though not all of them will succeed, these new enterprises will form the basis of the commercial success predicted. The Government should examine how best to encourage the investment of risk capital in such enterprises in the United Kingdom by changes in fiscal policy designed to provide the necessary incentives. Hitherto fiscal policy, including the budget measures to encourage small firms (mentioned in paragraph 9 of the White Paper) has done little to counter the poor response in this country. This all stands in marked contrast to the situation in the U.S.A. where tax reliefs have played a major role in the rapid development of such companies. We recognize that the Government's recent decision over tax relief for investors should help; we hope that this will be but one element in a larger package designed to help the growth of biotechnology industries.

9. In summary, therefore, whereas private industry and the public sector alike were looking for active encouragement and a clear policy, we can find little encouragement in the Government's response to the importance and urgency stressed in the Report of the Working Party on Biotechnology.

15 June 1981

MEMORANDUM SUBMITTED BY THE
ASSOCIATION OF SCIENTIFIC, TECHNICAL AND MANAGERIAL STAFFS

APPENDIX 10

Memorandum Submitted by the Association of Scientific, Technical and Managerial Staffs

BIOTECHNOLOGY (B 23)

We are pleased that the Select Committee is conducting an enquiry into biotechnology. We understand that the Committee will produce an interim and a final report. We submit these observations for the interim report and will submit a more detailed paper later in the year. We would also welcome an opportunity to give oral evidence to the Committee during its enquiry.

ASTMS is the largest white-collar union covering both the public and private sectors, with a membership of 490,000. ASTMS represents professional, scientific, technical and engineering staffs in a very wide range of industries and occupations. Members include biologists, chemists, biochemists, mechanical engineers, chemical engineers, professional engineers, engineering technicians, university lecturers, research and development workers in many fields, pharmacists, and doctors. They work in virtually every industry, ranging from the more traditional such as textiles, through vehicle manufacture and chemicals to the oil industry and nuclear power industry, and in many service industries such as finance, education, the National Health Service and medical research.

ASTMS has a wide-ranging interest in the development of biotechnology. The education, training, career opportunities and working conditions of our current and future members will be affected by decisions taken now about the development of biotechnology. We are naturally concerned that industries in which our members now work may be rendered obsolete by the new technology. Finally, and perhaps of most importance, we are extremely concerned at the lack of economic and social progress in Britain today. We are well aware of the importance of biotechnology to the future economic prosperity and employment opportunities of the country. We fear that Britain, in spite of a very strong research contribution to this field, will fail to exploit developments in this field industrially and that as a consequence the health and general well-being of our nation will suffer.

Processes involving biotechnology will undoubtedly play an increasingly significant role in the economy over the next few decades. Some of these processes can have a very long lead in time, ten, sometimes twenty years, between the initial research and full industrial application and production. Others may be able to be applied very rapidly, but in either case, investment decisions must be made now if we are to see a maximum application of these very powerful technologies in the building of a health economy. Biotechnology will be economically important because many products will be able to be produced more cheaply and from renewable resources. There will be social implications for health care, with the provision of new pharmaceuticals and a widening of diagnosis and prevention of genetic handicap. Politically, the development of disease-resistant crops and the alteration of protein production could help the Third World to produce adequate food.

Other major industrial countries are investing heavily in biotechnology; this is an area where it could be economic suicide to be left behind. If other countries obtain key patents on micro-organisms, and the processes to utilise them, it will cost Britain large sums to purchase this technology—often based on research findings from the UK. At the moment, we still have the expertise necessary to develop and exploit biotechnology, but we are at risk of losing it to our competitors because of insufficient investment, poor facilities and inadequate career prospects for our trained personnel.

The proper development of biotechnology will mean significant employment opportunities, not just in research and development laboratories, but also in designing and producing the machinery that will make use of the discoveries, and in the actual manufacturing processes which will result from them. There should be a steady, planned approach to the way in which biotechnological processes replace the more traditional processes and industries, so as to cause the minimum of disruption to employment patterns and industrial output.

MEMORANDUM SUBMITTED BY THE ASSOCIATION OF SCIENTIFIC, TECHNICAL AND MANAGERIAL STAFFS

It is also of overriding concern to society as a whole that there is a clear, coherent approach towards the health, safety and ethical aspects of biotechnology. We would wish to see a commitment that the benefits to be derived from this new technology will accrue to the whole of society and not be seen as the exclusive preserve of a few companies and individuals.

ASTMS identifies five main areas of concern.

1. INVESTMENT

Commitment from both the Government and the private sector to extensive investment in biotechnology is essential if we are to take full advantage of the opportunities it offers and not fall even further behind our major industrial competitors. A lack of investment in this field could lead to structural industrial underdevelopment, a process which (as we see from the history of the British electronics industry) is extremely difficult to reverse.

ASTMS is extremely worried by the Government's attitude to the problem of investment as evidenced by their White Paper on Biotechnology (Cmnd. 8177). Whilst they appear to realise that British industry is lagging behind foreign competitors, no practical proposals are put for government action, investment or incentives to industry. Instead, Ministers appear to display a touching but unfounded faith in the power of private industry to meet this challenge unaided. There is no evidence to support this assumption; in fact, national trends contradict it. In a time of recession and falling profits companies make immediate cash savings by cutting back in the fields of research and development and investment. This is reflected in the fall of 21 per cent in manufacturing investment in Britain since mid-1979. The level fell by 15 per cent in 1981 alone. Without radical changes and major government assistance, private industry will not be the vanguard of *any* significant new technological developments.

This is recognised in other major industrialised countries, all of which are using government funding to encourage the development of biotechnology. Bodies as varied as the Organisation for Economic Cooperation and Development (OECD), the European Economic Community (EEC) and the Advisory Council for Applied Research and Development in Britain (ACARD) have pointed to the need for substantial governmental investment in order to develop biotechnology to its full potential. This is particularly relevant in this field, as the commercial applications of research and development are not always immediately evident.

Other countries have already invested substantial sums: in Germany the Gesellschaft Fur Biotechnologische Forschung invested £35m between 1972 and 1978, and is now spending £5m a year and employing 250 people. In addition the Federal Ministry of Research and Technology (BMFT) spent £10m of its 1980 research budget on biotechnology. The United States government allowed \$150m of its 1981 budget for Research and Development in biotechnology although expecting the main effort to come from commercial companies. The Spinks Report ("Biotechnology", HMSO, March 1980) estimated that the Japanese government directs about £8m a year into biotechnology (this has recently been increased markedly), and there is additional Science Council support in this field for about 100 universities. In addition, in these countries there are likely to be substantial sums invested from general technology or investment budgets but not separately identified as being for biotechnology. To give some idea of the scale of overall investment, in the 1980 fiscal year the Japan Development Bank lent about \$4.5 billion to encourage loans by commercial banks.

These figures, whilst not definitive, give some idea of the scale of the problem and suggest that the £4–5m which the Spinks Report suggests the Government and Research Councils are now spending annually on biotechnology research is woefully inadequate.

MEMORANDUM SUBMITTED BY THE
ASSOCIATION OF SCIENTIFIC, TECHNICAL AND MANAGERIAL STAFFS

There is clearly a role for co-operation between the private and public sectors for investment in this field, in joint ventures such as Celltech, the new biotechnology company in which the National Enterprise Board holds a 44 per cent stake, the remaining shares being distributed among private investors.

When public money is invested the Government body involved should retain majority control so that they can continue to influence the direction of the research and development, and can ensure that a share of the benefits from the investment of public money are returned to the public. We are particularly concerned at the Government's comment in the White Paper on biotechnology (Point 26) that projects started with help from the British Technology Group will somehow become "fully independent" within a few years. As well as being unrealistic, this is a case of dogmatic "privatisation" which disregards the practical problems involved and which seeks to deprive the public of the possible long-term benefits of successful public investment. It also ignores the fact that many scientists and engineers wish to see their work used in a socially useful way rather than judged solely on profitability.

ASTMS are however pleased that the Government took the initiative in establishing Celltech and we believe that the formation of similar companies relating to other areas of biotechnology is probably the most appropriate route for further investment. However, as suggested above, we believe that the public sector should hold at least 51 per cent of the interest in these bodies.

Another way in which the Government might help would be to earmark a certain amount of Government money for providing tax concessions to small, highly capitalised, innovative companies in this area, as happens in the US and Japan.

2. EDUCATION

The provision of adequate financial support for the development of biotechnology is one side of the golden coin. The other is the construction and maintenance of an education system able to meet the demands of this new technology.

Every part of the education system is important. Today's primary school children will be the postgraduates of the next generation of biotechnologists. We must plan now to ensure that there are sufficient opportunities to keep our good young scientists in Britain. Otherwise, their expertise will go towards developing products for our overseas competitors. There is already evidence of a selective and damaging "brain drain" of some of the most able British scientists and technicians in this field, particularly to France and the United States.

Although comparatively few people are employed in biotechnology at the moment, if the field expands as we suggest, it will be requiring large numbers of skilled employees in many different scientific areas within 10–15 years. Therefore a strengthening of science teaching in schools, from the earliest age, is an important element of success. The Government's present cut-back in education is especially worrying in this context; primary schools that do not have enough money for books are not likely to invest in mini-computers. Further up the education scale, the cut-back in university places will deprive a significant part of a whole generation of fifth- and sixth-formers from gaining the sort of background likely to be needed in the industry of the 1980s and 1990s.

It is estimated that in the academic year 1983–1984 20,000 university places will be lost. Because of the increase of the 17- and 18-year-old age group that year it will mean that 44,000 people who otherwise might have gone to university will be deprived of that chance. Although the Government has expressed a preference for science compared with arts and social science education, the cuts have hit hardest at the technology-based, industry-linked universities. It is likely that a large proportion of the places lost will be science places. The cutbacks also drastically affect the number of university teaching posts, restrict the

MEMORANDUM SUBMITTED BY THE
ASSOCIATION OF SCIENTIFIC, TECHNICAL AND MANAGERIAL STAFFS

career opportunities for bright young lecturers and curtail important university-based research. We are opposed to the cuts in further and higher education, and are particularly alarmed at their indiscriminate nature, which leads to a maximum deleterious effect on the very fields in biotechnology which most require support.

It is not just academics and trade unions who are concerned with the implications of these cuts; the major Swiss-based biotechnology company Biogen recently stated that they had decided against siting new laboratories in Britain because of the massive cuts in British higher education.

We must also tackle the problem of scientists in their mid-20s or early 30s who see little prospect of career advancement in the universities or industry of this country, and so move abroad to work. This can be done by long-term planning which includes a drastic reduction in short-term contracts and proper salaries, career structure and job security for our bright young scientists—negotiated by professional union negotiators.

3. CENTRES OF EXCELLENCE

There can be an important role for "centres of excellence" in biotechnology providing they are not used as an excuse for underprovision of facilities or finance in other areas. Their exact form would have to emerge from discussions between the Government, industry, the universities, the Research Councils and trade unions, but in outline we would envisage several centres spread geographically, not just at London or Oxbridge. Each would be based on a university or polytechnic and would combine and co-ordinate the disciplines of molecular biology, biochemistry, microbiology, engineering, computing and so on. They would maintain links with industry (both public and private sector), act as a focus for Research Council and industrial grants, and concentrate on particular fields of biotechnological research. The academics involved need not all be employed at that particular centre, and the industries involved do not necessarily have to be locally based.

Such centres would provide the opportunity for more interchange of ideas and personnel between universities and industry than occurs at the moment. This would benefit both the universities and industry in the co-ordination and advancement of research.

These centres could fill the current gap between the excellent research being done in British universities, and its exploitation by industry to produce useful products and generally improve the economy. This gap is huge at the moment, and is a significant impediment to economic development in Britain. The centres could also demonstrate to some of our more cloistered academics that their talents ought to be applied to socially useful projects. If salaries, conditions and facilities are sufficient to attract high calibre scientific teams and if industry, academic institutions and the public all see benefits from these centres, then there will be no problem in maintaining them.

In other countries private industry invests far more in education than in Britain. There are different ways in which this can be done, including the sponsorship of students with a guarantee of a post on qualifying, financing particular projects, making donations to universities, and sponsoring particular Chairs. This is an area which has to be approached with some caution because of possible conflicts between commercial considerations and academic freedom, or private industry finance being seen as a replacement for Government expenditure on education, but it remains an area worth exploring.

It would be advantageous to both industrialists and academics if it were made easier for individuals to "swap" jobs for periods from several months to several years. At the moment there are a number of impediments to this (such as non-interchangeable pension schemes) which could be overcome if there was sufficient commitment to this form of "cross-fertilisation". It is likely to be of benefit to

industry and the society generally if academics are made to think more about the possible practical applications of their research. This would be assisted both by greater contact with industry and by greater interaction between academics in related disciplines, for example biology and engineering.

The Research Councils should provide an important avenue of investment for a wide range of university research in this area, both in and beyond the "centres of excellence". As biotechnology cuts across their areas of interest and expertise we agree with the suggestion of the Advisory Council for Applied Research and Development (ACARD) that ACARD and the Advisory Board for the Research Councils should set up a joint committee for biotechnology to develop and co-ordinate a coherent programme of biotechnology research. We would add that this should have an input from industry, trade unions and Parliament, perhaps through the body we outline in our next section.

4. DIRECTION OF RESEARCH AND DEVELOPMENT

The development—or failure to develop—the potential of biotechnology is of such significance to the country as a whole that the pattern of development cannot be left to chance, or to the interests of particular companies or scientists.

Again we feel concerned at the White Paper on biotechnology which seemed to accept that all development would come from random initiative from private industry. Apart from our conviction that the level of investment required would not be reached, it is clear that what investment there is would naturally be concentrated in areas likely to lead to short-term profit rather than long-term structural economic advance. Whilst profit making will be an important element of the development of biotechnology (for the public sector as well as the private sector) it must not be the only or even the major determinant of which areas are developed. There must be a social input, from the earliest stage of deciding where research funding will be directed, right through to the final stages of deciding whether and how the research will be put to practical application.

This social input should ensure:—

(1) that society as a whole gains—for example less pollution, better drugs—even where these developments do not necessarily involve immediate financial profit;

(2) that profits which accrue from public investment are used for the public good;

(3) that the proper conditions are created for retaining good scientists in Britain;

(4) that research is co-ordinated to the extent that there is no significant overlap (and thus waste) of resources, and

(5) that the seed-corn of a strong future biotechnology sector is not sacrificed to short-term profits.

A body comprising representatives from Government, Research Councils, trade unions, universities and industry should co-ordinate work in the biotechnology field, with power to recommend to the Government which particular areas need investment or other assistance, and what controls or regulations are needed to ensure a coherent comprehensive development of this field.

5. ETHICAL AND SAFETY CONSIDERATIONS

ASTMS supports the expansion and application of biotechnology, but we are equally concerned with its safe and ethical use. These considerations, far from being mutually exclusive, can complement one another, given appropriate local and national safe-guards. Among the ethical questions that will arise are the

MEMORANDUM SUBMITTED BY THE
ASSOCIATION OF SCIENTIFIC, TECHNICAL AND MANAGERIAL STAFFS

application of recombinant DNA technology to altering the human genome, the private use of human gene clones for profit, and the patenting of newly devised synthetic organisms. If, for example, a monoclonal antibody is developed by a British university for treatment of an endemic disease in the Third World, should it just be on sale to the highest bidder? How much interchange of information and materials (e.g. host-vector systems for recombinant DNA work) can there be between scientists in a commercially competitive area? How much influence should private industry have over the direction of research or use of the products developed from research?

Whilst much of the work in biotechnology is unlikely to pose important risks to people or the environment, we feel that there may still be special hazards associated with it. We say this in full knowledge of the fact that the potential risks of recombinant DNA work are probably less than once envisaged. However, significant areas of uncertainty remain. We are not sure that the use of transmissible vectors to study human cancer genes is safe, nor that toxic or biologically potent substances should be specified by clones in systems that are not disabled and subject to strict scrutiny by an independent government committee, such as the Genetic Manipulation Advisory Group (GMAG).

We have already come across health problems among workers in biotechnological factories as diverse as those producing enzyme washing powders and those producing contraceptive pills. A report by Sargeant and Evans to the Common Market (Study Contract No. 430–78–5 ECI UK/MB, December 1978) outlines some hazards unique to biotechnology.

There is a qualitative difference from the hazards associated with, for example, the chemical industry, as the agents used in microbiology are alive and can multiply and persist in the environment unless carefully disabled beforehand. A chemical spillage can cause considerable damage at the time but it usually disperses within a comparatively short period. In contrast, if a micro-organism that, for example, digests oil or infects crops, escapes into the environment and establishes itself, it could do irreversible damage. The continuance of external safety controls through GMAG, and similar bodies, which are both independent and enforceable, is a cornerstone of our policy on biotechnology. It is essential that safety considerations are built into biotechnology from the start.

All developments should be considered from an ethical and safety viewpoint by a public body including representatives of Government, unions, universities and industry (but distinct from the "development" body outlined above). The body should be responsible to Parliament but its members should be appointed or elected by the groups they represent to ensure public confidence.

The ideal body to take on these responsibilities is already in existence, costs the Government next to nothing, and has to date amassed considerable knowledge and experience in the field. It is the Genetic Manipulation Advisory Group (GMAG) of the Department of Education and Science, which currently gives advice on the safety problems associated with recombinant DNA work. GMAG could also take on the consideration of ethical problems arising from recombinant DNA work, and problems associated with other areas of biotechnology. GMAG comprises scientific and medical experts, representatives of the public interest, trade unions and employers, and "assessors" from relevant Government departments. It currently advises those involved in genetic manipulation, undertakes a continuing assessment of risks and precautions—in particular of any new methods of physical or biological containment—and of any newly developed techniques for genetic manipulation and advises on appropriate action. It also liaises with relevant Government departments, the Health and Safety Executive and the Advisory Committee on Dangerous Pathogens, and makes available advice on general matters connected with the safety of genetic manipulation including health monitoring and the training of staff.

GMAG has our continuing support and although its role may alter as it becomes possible to more closely define the hazards of DNA work, and the Group begins to consider some of the social and ethical implications of this work, we feel that it should continue to play an important part in the development of biotechnology. GMAG is probably the committee with the greatest expertise in understanding both the problems and the potential of recombinant DNA technology.

CONCLUSION

1. The Government must be prepared to invest if they wish to see returns. The development of biotechnology is vital to the future prosperity and well-being of Britain. If this Government's concern for our future goes any deeper than rhetoric, it will take immediate steps to increase substantially public expenditure on (a) education, (b) research and development, (c) industry in which the public will hold a significant stake, and (d) tax incentives to innovative companies in this area.

2. We must ensure that we retain our good young scientists. We need a strengthening of science teaching in schools, a planned increase in relevant university places, and an abundance of attractive career opportunities. This must include a drastic reduction in short-term contracts and internationally competitive salaries.

3. Several "Centres of Excellence" in Biotechnology should be established in different parts of the country, based on academic institutions. They would bring together the various scientific disciplines required to develop the new technology, and provide important links between industry (both public and private sector), the Research Councils and academic institutions.

4. The Government should establish a committee to oversee a coherent and co-ordinated development of biotechnology and to ensure that the benefits of the new technology accrue to all sections of society. The Committee should include representatives from Government, Research Councils, trade unions, universities and industry.

5. The Government can ensure that ethical and safety problems are properly dealt with by referring them to the Genetic Manipulation Advisory Group—to ensure safe and ethical practice, to meet a real public concern, and to get as wide an input as possible into these problems. The existence of GMAG has allowed recombinant DNA work to progress with a good deal of public confidence. Expanding its remit to cover other safety and ethical problems of biotechnology would extend that public confidence to those areas.

APPENDIX 11

Memorandum Submitted by the British Veterinary Association

BIOTECHNOLOGY IN THE UK: TRAINING, RESEARCH AND INDUSTRIAL APPLICATION (B 24)
THE PROTECTION OF THE RESEARCH BASE

1. The agricultural industry could and should be a major beneficiary of the application of biotechnology during the next decade. The major part of the work carried out by the members of the Association lies in the application and development of basic principles rather than studies on fundamental aspects as at the "centres of excellence". Although it is correct to protect and maintain such centres it is equally important to evaluate the potential uses of biotechnology for the benefit of British agriculture.

Memorandum Submitted by the British Veterinary Association

2. Biotechnology is likely to affect both veterinary medicine and animal production. Examples of the use of manipulative techniques in veterinary science includes:—

(a) The production of specific vaccines against foot and mouth disease, rabies, infectious bronchitis of poultry and transmissible gastro-enteritis of pigs. Advantages embrace (i) economy of production, (ii) security and safety, and (iii) greater potency and ease of assay.

(b) The development of improved diagnostic reagents utilising monoclonal antibodies. In addition to their use for the identification of infectious agents and for epidemiological purposes (e.g. strain identification) such antibodies can be employed for the measurement of hormonal and other residues in animal tissues and meat. They may also facilitate antigen (protein) purification. Monoclonal antibodies may also be used for pregnancy diagnosis on farm animals.

(c) Large scale production of natural hormones such as bovine growth hormone, the daily administration of which to dairy cattle has been shown to increase daily milk yield by approximately 15 per cent throughout lactation. Hormone substitution therapy is also increasingly required in small animal medicine.

(d) Conversion of wastes to animal feedstuffs (e.g. waste lactose from cheese manufacture).

(e) Production of cheap protein from microbial (single cell protein) or fungal culture (e.g. ICI's "Pruteen"). This could lead to a reduction in protein imports and reduced disease risk.

(f) Improved methods for producing antibiotics and interferons.

3. Techniques relating to veterinary problems are being developed at several ARC institutes (e.g. the Institute of Animal Physiology, Babraham; the Animal Virus Research Institute, Pirbright; the Poultry Research Station, Houghton; the Institute for Research on Animal Diseases, Compton; and the Animal Diseases Research Association, Edinburgh), the Central Veterinary Laboratory of the Ministry of Agriculture, Fisheries and Food, Weybridge, certain university departments and various pharmaceutical companies.

4. The current structure and funding of veterinary research has resulted in a number of small units being built up at several different institutes. Many staff have been transferred from other existing projects and only a few new specialist workers have been recruited.

5. In order to progress in this rapidly developing field and to benefit from the UK lead in the basic concepts extra funding is needed to organise enthusiastic project groups with sufficiently wide expertise. In this way projects could be followed through from the initial application of the basic concept to the stage of biological production. Effective collaboration between the publicly funded research sector and commercial organisations may also be required. Up to now, in the areas of animal disease and production, funding to enable effective UK utilisation of biotechnology has not been forthcoming.

6. The British Veterinary Association represents 8,000 veterinary surgeons in general practice, research, state service and as advisors to commercial organisations. The Association is keenly interested in animal welfare and would like to see priority given to those areas of research which will advance veterinary science.

May 1982

MEMORANDUM SUBMITTED BY THE
GLAXO GROUP RESEARCH LIMITED

APPENDIX 12

Memorandum Submitted by the Glaxo Group Research Limited

BIOTECHNOLOGY IN THE UK: TRAINING, RESEARCH AND INDUSTRIAL APPLICATION (B 25)
PRESENT AND FUTURE SCOPE OF BIOTECHNOLOGY

The established biotechnology industry is based upon fermentation processes. The most sophisticated development in this area relates to the production of antibiotics. The new growth areas of biotechnology are genetic engineering (recombinant DNA technology) and monoclonal antibody production and utilisation. Both of these new biotechnologies have grown rapidly from a broad base of intensive academic research. In tracing the development of these biotechnologies certain key scientific publications are cited. However it should not be forgotten that "breakthroughs" can usually only take place in the right scientific climate. Very many separate pieces of first class sciences are brought together at any of the apparent breakthroughs in a scientific field.

By the very nature of things, one cannot accurately predict in which particular area of biosciences the next breakthrough applicable to biotechnology will occur. One can, with some confidence, say that it will only occur within a strong and flourishing scientific community.

The research base for biotechnology. Modern biotechnologies have grown out of fundamental academic research. In the UK this research has been supported by the dual funding system in the universities and with particular success by the Medical Research Council funding of centres of excellence, in the form of Units and Institutes. (In the United States the vast amount of excellent biological research that has led to developments in the new biotechnologies, has been largely funded by the National Institutes of Health, even when such research has been carried out at private universities and institutions.)

In the UK at the present time the dual funding system is breaking down. The UGC grant is no longer providing the well-found laboratory upon which research council grants have been based. Research council funding is swinging towards shorter-term grants and fewer research personnel. Two consequences of these policies can be predicted: 1. there will be a curtailment of the excellent academic research base that is necessary to support current commercial developments in biotechnology and which will be essential for future innovations in biotechnology: 2. there will be a dearth of well-trained young scientists to supply the needs of commercial biotechnology companies.

Academic-industrial links. In the new biotechnologies close academic-industrial links are extremely important. The time lag between research results in the academic laboratory and applications in biotechnology-based industry is very short relative to the time lag for applications of other areas of academic research.

The best Government-funded schemes for encouraging such links are those run by SERC, i.e. CASE studentship awards and Cooperative Awards. Such excellent schemes should be extended. Both CASE and Cooperative Award schemes are relatively inexpensive to operate. Their major usefulness to industry lies in the provision of a meeting point for academic and industrial scientists focusing on problems generally of more long term academic interest. The usefulness of these schemes to the universities clearly lies in the provision of support for on-going academic projects and in improvement of the nature and quality of training, both practical and intellectual, provided for students.

Direct links between industry and academia in the field of biotechnology can be initiated by either the industrial partner or the academic partner. Government could play a useful role in acting as honest broker to bring the sides together. Links that involve specific

projects such as the cloning of a particular gene or the production of a particular monoclonal antibody are likely to be contracts placed by the industrial partner. In deciding to undertake such specific contract work University departments should be sure that the scientific value of the project is valid in their own terms or research progress and research training.

It is disturbing to see that some bias is growing up against industrial academic links in the area of biotechnology. Hostility towards industrial incursions into academia is being displayed by certain academics. I feel that this hostility is largely arising from, and is certainly aggravated by, the increasing necessity for academic departments to obtain support from outwith the dual funding system. It would clearly be inappropriate for most academic departments to become too highly dependent upon industrial funding. An academic department must maintain a balance between research grants and UGC support on the one hand and industrial contracts and co-operative awards on the other hand. It should be recognised that even within departments possessing the skills and expertise relevant to biotechnology not every group can attract industrial support. Therefore a disproportionate influx of industrial money may occur and this will lead to unnecessary tensions, increasing those that already exist in the present economic climate. The idea that making it more difficult to obtain Research Council and UGC funding will encourage Bioscience Departments to turn to industry for support and thereby strengthen links between academia and industry, is clearly an oversimplification and in some instances may be counterproductive.

CONCLUSIONS

In summary, industry using biotechnology is willing to put money into academic departments provided that 1. there is good on-going research to attract the interest of the industrial partner, and 2. there is a balance of funding between non-industrial and industrial sources supporting research so that the department in question does not lose its overall academic credibility.

Finally, in looking at the research base for biotechnology it should be borne in mind that innovations and discoveries in the most esoteric areas of biology (certainly unlikely to attract industrial funding) might well be the starting point for new developments in biotechnology in the not too distant future. It is not many years ago that plasmids and restriction enzymes, the present day tools of the genetic engineer, were just such areas of esoteric academic research.

25 May 1982

APPENDIX 13

Memorandum Submitted by the Public Health Laboratory Service Board

BIOTECHNOLOGY IN THE PUBLIC HEALTH LABORATORY SERVICE (PHLS) (B 26)

1. LEGISLATIVE BACKGROUND

1.1. In 1945 the Government decided to put the wartime Emergency Public Health Laboratory Service on a permanent footing and statutory authority was given in Section 17 of the National Health Service Act 1948 for the Minister to provide a bacteriological service for the control of the spread of infectious diseases.

1.2. The Public Health Laboratory Service Act 1960 established a PHLS Board as a new statutory body, capable of acting in its own right as agent for the Minister of Health. The staff of the Service were transferred from the employment of the Medical Research Council, which had administered the Service hitherto, to the Board.

Memorandum Submitted by the Public Health Laboratory Service Board

1.3. The National Health Service Act 1977 (Schedule 3) incorporated the PHLS Board, introducing some new minor provisions.

2. The PHLS Centre for Applied Microbiology and Research

2.1. The PHLS Act 1978 was framed to allow the PHLS Board to accept an invitation from the Secretary of State for Social Services to become the management authority for the former Microbiological Research Establishment (MRE) of the Ministry of Defence at Porton Down. This took effect on April 1, 1979. The Act extended the Board's powers, allowing it to "carry out such other activities as, in the Secretary of State's opinion can be conveniently carried out in conjunction with the Service". The Board renamed the Establishment the PHLS Centre for Applied Microbiology and Research.

2.2. In his invitation, the Secretary of State stipulated that the former MRE should continue as a civil establishment on a reduced scale broadly on lines suggested by a Committee of the Medical Research Council in 1977. This had recommended that it should undertake activity in four closely inter-related areas and that in addition to meeting a national need in these areas, it might to some degree be self-financing. The areas were: microbial products, exotic or dangerous pathogens, aerobiology and biological safety. The Board recognised that among the new activities for which it was now responsible, it had no experience in the management of vaccine production nor in the development and manufacture of microbial products for sale. Consequently, it extended its membership to include persons from commerce and industry who possessed the requisite skills.

2.3. To advise the Board on the overall policy it should adopt on income generating activities, and to expose CAMR to expert commercial and professional advice, the Board established a Standing Committee on Income Generating Activities under the Chairmanship of Professor M. H. Richmond, FRS. This was formed to optimize the income earned by the Centre consistent with its overall role, so as to relieve public funds of some of the cost of CAMR. A system for producing accurate costings within the Centre, for commercial purposes, has been developed by Coopers, Lybrand and Associates Ltd.

2.4. An outline of the structure of the Centre is attached as Appendix I. It should be noted that the word "Laboratory" is used to describe what are, in effect, large Departments or Divisions (for example, the Microbial Technology Laboratory has a staff of about 70, and includes a Fermentation Pilot Plant, likewise the Vaccine Research and Production Laboratory includes a new, licensed, manufacturing unit built by foreign capital at a cost of £750,000).

3. Structure and Functions of PHLS

3.1. The PHLS, of which CAMR is part, consists of a centrally coordinated network of medical microbiology laboratories throughout England and Wales. The Service is concerned with the diagnosis, prevention and control of communicable disease. Most of its 52 Regional and Area Laboratories are in hospitals, and these are backed up by the specialised services provided by Reference Laboratories which are grouped at Colindale and Porton Down. Through its active participation at "grass roots" level in many of the leading departments of pathology of the country's hospitals, the PHLS is uniquely placed to gather background information on some of the areas of health care where biotechnological exploitation can be applied. This is particularly true of the use of diagnostic reagents and the evaluation of vaccines, or other therapeutic or prophylactic agents active in infections.

3.2. PHLS is funded from the Health vote as part of the centrally funded services of the Department of Health and Social Security. The total revenue allocated to the PHLS Board for 1982–83 is £28·58m, a decrease in real terms compared with the previous year. The staff totalling some 2,250 are distributed among the medical, scientific, technical, clerical and ancillary grades. They are employed on NHS terms and conditions of service.

Memorandum Submitted by the Public Health Laboratory Service Board

4. Biotechnology

4.1. Biotechnology is seen by the Board as a composite technology, in three important elements of which—genetic manipulation, enzyme technology and fermentation—CAMR is particularly strong. It is the Board's view that it should foster research and development in these inter-related areas mainly, though not exclusively, in the medical field, for it is here that the professional expertise of the PHLS in medical and environment microbiology can be brought to bear with the greatest prospect of success.

4.2. Although CAMR is the main contributor, the activities of other PHLS laboratories are also relevant to the total biotechnological effort of the Service. This is particularly true of the following:—

(a) *The National Collection of Type Cultures*

This laboratory is a depository of international standing for cultures of bacteria of medical importance, including strains used in genetic manipulation. Besides cataloguing, preserving, verifying and issuing authenticated cultures to scientific workers at home and overseas, it provides a service for the identification of "difficult" organisms.

(b) *The Mycological Reference Laboratory*

This laboratory houses the National Collection of Pathogenic Fungi and, on a much smaller scale, offers a similar service in respect of fungi as the National Collection of Type Cultures does for bacteria.

(c) *The Division of Microbiological Reagents and Quality Control*

This laboratory is a major Division of the Central Public Health Laboratory, Colindale. It is engaged in the development of new microbiological reagents and diagnostic methods, including the use of monoclonal antibodies, for the recognition of microbial infections. It also monitors the quality, in terms of technical performance, of new and established microbiological diagnostic products.

(d) *The Epidemiological Research Laboratory*

This unit is also based at Colindale. It is responsible for the scientific surveillance of the use of vaccines and other immunological products. It is thus the main source of information for the DHSS and others on the efficacy and adverse effects, if any, of immunisation. The laboratory works closely with the National Institute of Biological Standards and Control and the relevant committees of the Medical Research Council and the DHSS.

5. Biotechnology at CAMR

5.1. Three themes dominate the scientific programme at CAMR. The first is the diagnosis of, and research into, highly dangerous (i.e. infectious) pathogens, particularly those which cause the viral haemorrhagic fevers (Lassa fever, Marburg and Ebola), smallpox and rabies. The second is microbiological safety, which has long been a strength at Porton. The third is biotechnology.

5.2. CAMR does not aim to have programmes in all the fields envisaged in the Government White Paper on Biotechnology. To attempt to do so would diffuse resources too widely. Its main thrust is in the health care field, for the following reasons:—

(a) Most of the successes in biotechnology so far have been with medically-orientated products such as insulin, interferon, and growth hormone which fall into the low volume, high cost, market. No one has yet solved the problems of applying the newer biotechnological methods to products in the high, volume, low cost field, producing goods which might compete with existing fuels, foods or plastics.

(b) It is the field in which PHLS has expertise and knowledge.

(c) The Centre is funded, via the PHLS Board, from the Health Vote (see 3.2).

MEMORANDUM SUBMITTED BY THE
PUBLIC HEALTH LABORATORY SERVICE BOARD

5.3. In non-medical biotechnology CAMR at present has two research projects. The first is with Cadbury-Schweppes, the other (on the production of ethanol from biomass) is with Technoferm Developments, a subsidiary of the Mitchell Cotts-Lennon Group. The agreements with these two companies give to CAMR the right to use any consequent discoveries which are relevant to the health care field.

5.4 The three laboratories most directly concerned with biotechnology are: Vaccine Research and Production, Microbial Technology, and Therapeutic Products. Their research programmes, however, necessitate a substantial infrastructure of laboratories able to support their work at a more fundamental level. Thus, the Pathogenic Microbes Research Laboratory has considerable knowledge of fermentation technology, especially by continuous culture, and insight into related aspects of bacterial physiology. Likewise, the Molecular Genetics Laboratory contains a group highly experienced in genetic manipulation. Laboratory safety underpins all research at CAMR and is monitored through the Environmental Microbiology and Safety Reference Library.

Vaccine Research and Production Laboratory

5.5. This laboratory has recently acquired a new Vaccine Virus Concentrate Production Unit (2.4), for the manufacture of tick-borne encephalitis vaccine, built by a British firm (Clean Room Construction Ltd.) for an Austrian pharmaceutical company (Immuno AG). Killed viral concentrate produced in this unit is sold to Immuno AG for finishing, packaging and distribution in Austria, West Germany, and elsewhere. Other vaccines produced at CAMR are those needed in such small amounts in the UK as to be unattractive to commercial firms. Examples are anthrax vaccine, and toxoids for immunisation against botulism.

5.6. The laboratory has the task of developing new vaccines, with the aim of licensing a firm to produce them after completion of clinical trials. Examples under development include vaccines for viruses of the herpes group, and hepatitis B. The laboratory also has projects concerned with plasmid stability, and the use of monoclonal antibodies to separate the protective antigens of pathogenic organisms. The future will see research into subunit vaccines, using genetic manipulation. One such programme is already under way, with a commercial firm showing interest.

Microbial Technology Laboratory.

5.7. This laboratory includes the Fermentation Pilot Plant, where organisms can be grown at volumes of up to 400 litres. A collaborative research programme with Kabi-Vitrum AB (the Swedish state-owned pharmaceutical company) has enabled CAMR to ferment a genetically engineered strain of *E. coli,* developed by Genentech of California, which produces human growth hormone. Scale-up of genetically engineered microbial systems, a key area in the whole field of biotechnology, is one in which CAMR holds a strong position. Other microbial systems are fermented to produce therapeutic and diagnostic enzymes. Examples of the former are asparaginase (used to treat childhood lymphatic leukaemia) and phenylalanine ammonia lyase (under trial as an oral treatment of phenylketonuria). Potential therapeutic substances under development include a novel class of enzymes for lysing blood clots, and new drugs which may be of value against cancer.

5.8. Enzymes for use as diagnostic reagents are an important field, and the Spinks Report drew attention to the lack of UK suppliers of biochemical reagents. Enzymes for estimating plasma lipids, paracetamol, and methotrexate have recently been patented and others are under development.

5.9. The possibility of using microbial systems to break down toxic aromatic chlorohydrocarbons, and to sequester mercury and cadmium in environmental waste materials, is being investigated under a research programme sponsored by the Department of the Environment.

APPENDIX I TO THE MEMORANDUM SUBMITTED BY THE
PUBLIC HEALTH LABORATORY SERVICE BOARD

5.10. Among the other activities of the laboratory is an interest in protein chemistry, especially protein separation. The twinning of high performance liquid chromatography (HPLC) with reactive triazine dyes ("Procion" Dyes—ICI) into a chromatographic method for protein separation, termed High Performance Liquid Affinity Chromatography (HPLAC), has recently been patented. In addition, study of plasmid vectors and the use of "alternative" hosts (bacilli and yeasts) for genetic manipulation is in progress; for instance, the use for this purpose of *B. subtilis* has been a subject of collaboration between Biogen at Geneva and CAMR.

Therapeutic Products Laboratory

5.11. This laboratory processes and purifies therapeutic enzymes, especially asparaginase, which has been produced by fermentation in the Pilot Plant. The laboratory also receives, on behalf of DHSS, autopsied human pituitaries, from which it extracts and purifies human growth and other invaluable hormones, for clinical use.

New Facilities

5.12. The DHSS has given (2J) approval for the building of a new Production Centre at CAMR, separate from the main building. This will house enzyme finishing laboratories, and a clinical trial scale vaccine production unit. The DHSS has also approved, in principle, the building of a new, larger, and more modern Fermentation Pilot Plant on the CAMR site. This has been planned with the help of academics and industrialists.

6. CONSTRAINTS

6.1. The main difficulty is funding. The reduction in the revenue allocation to PHLS for 1982–83 will inevitably be felt in all areas of the work of the Service, including biotechnology.

6.2. The economic future of the nation depends on our ability not only to keep up with, but also to lead in the field of technological innovation. Neither will happen without substantial continuing investment in bodies like the PHLS, which are engaged in advancing biotechnology.

APPENDIX I

PUBLIC HEALTH LABORATORY SERVICE
CENTRE FOR APPLIED MICROBIOLOGY AND RESEARCH
PORTON DOWN, SALISBURY, WILTSHIRE

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APPENDIX 14

Letter from Professor Kenneth Murray, European Molecular Biology Laboratory, Heidelberg, to the Clerk to the Committee

BIOTECHNOLOGY (B 27)

With apologies for the long delay in doing so, I am responding to your circular of 16 March. In addition to my reply to your questionnaire, I should like to express a more personal view of some aspects of the current situation, for I have been closely concerned with the development of genetic engineering for some years.

The origin of the situation, it seems to me, is that although Industry and the various branches of the Government's Scientific Administration are now well aware of the changes that have been developing rapidly in biological science and their biotechnological applications, they have, with notable exceptions, been extremely slow to recognize and appreciate the opportunities presented and to make even moderate investments in them. As a result we are now woefully short of appropriated trained scientists in many areas, and attempts to redress this have also been less than adequate.

As long ago as 1973, for example, I described the new possible applications to one of our major pharmaceutical companies which is heavily based upon industrial fermentation and for which I worked many years ago. The scientists in the company were excited about the opportunities that the new developments presented, but were unable to raise any enthusiasm from the company's director of research or from the board. (Two years ago, i.e. seven years later, I believe that the board finally decided that it should begin to support research in this area.) At the same time, we were approached by another of the country's major companies, ICI Ltd, whose forward-planning group had identified genetic engineering as an area of possible future opportunity and it is no secret that these discussions led to the establishment of one of the Company's first Joint Research Schemes with a university department. This was a mutually useful and interesting experience for it gave us active contact with industry, and it certainly helped to establish the Company's inhouse activities in genetic engineering. This, however, was my only really positive experience in trying to arouse active interest in industry for genetic engineering. A few years ago, I was asked to lecture at the Society for Chemical Industry in London on applications of genetic engineering. There were 13 people in the audience and I think it is the only occasion on which I have felt so bored with my own lecture that I felt like walking out.

Letter from Professor Kenneth Murray, European Molecular Biology Laboratory, Heidelberg, to the Clerk to the Committee

In 1975 I was involved with others in convening a meeting at Oxford, sponsored by the Research Councils, to alert various sections of the British scientific community (including industry) to the opportunities that developments in genetic manipulation presented. The Research Councils were responsive to this and have played an important part in encouraging research in this area and in providing earmarked training grants. In general, industry appeared to be prepared to wait, however. In the meantime, the continual financial pressure to which universities have been subjected over the past few years and the really acute problem that they face at present, have adversely affected the country's ability to exploit and develop the opportunities in biology, especially after the rapid rise in popularity of biotechnology which was fed by the breakthrough in genetic engineering and which has already taken several of our good people abroad.

A few years ago, I became involved with one of the new companies established to develop the commercialisation of new development in biology, namely BIOGEN NV. This company was formed four years ago around a scientific board comprising a group of scientists with international reputations from a number of countries. The development of this Company has been interesting and scientifically exciting. An important feature has been the participation, as major investors, of a number of large established companies, but with the exception of the recent addition of the Grand Metropolitan Group, it proved extremely difficult to interest British industry in this organisation which is something that we all regret. The attitude in North America, however, was much more supportive and an important aspect of the Company's structure is that its financial investors bring more than money; they also provide expertise and experience from various relevant sectors of industry. I believe this is an important and powerful component in the development of a new company and it contrasts with attempts to establish a company with a mixture of Government and Institutional backing. We shall see in due course how Biogen and several other companies develop, but the way in which Biogen was set up has certainly provided an attractive environment in which to work, a superb scientific atmosphere, and the recruitment of scientific staff of very high quality indeed; this latter, in particular, is very auspicious for the future success of the company. To me, the structure and international status of the Company would make it a very attractive employment opportunity.

From my experiences over the past few years I believe that it would be more useful for the British Government to invest its support in the fundamental basis of our scientific future, particularly through selective support in universities by ensuring that we are able to replace staff, particularly academic staff in Science departments, by helping to provide an exciting scientific environment in the country, and by making financial investment in the area attractive to established companies, than by providing funds for the creation of companies through the BTG. Obviously, this is a personal opinion and is no doubt coloured by the fact that I expect to return shortly from a period of leave at the EMBL in Heidelberg to my Department where any position that becomes vacant will almost certainly have to be forfeited. Although opinions will vary widely in detail, I am sure that there will be unanimity that the present government policy towards the support of Education and Science is jeopardising the basis of the country's technology in the future.

I hope that my comments reach you in time to be of interest or use to your committee.

3 June 1982

APPENDIX 15

Memorandum Submitted by Dr R E Spier

BIOTECHNOLOGY: THE ROLE OF GOVERNMENT (B 28)

INTRODUCTION

In November 1981, an attempt was made by the British Coordinating Committee for Biotechnology (BCCB) to delineate a "Strategy for Biotechnology in the UK". This effort did not achieve its objectives so that there is still a basic requirement to define a program for Biotechnology in the UK. Clearly this involves central, ie. government agency involvement and hence it is necessary to establish the role of the UK Government in Biotechnology.

DEFINITIONS

If we define Biotechnology as "the use of living organisms (natural or engineered) or their components . . . to wealth generating ends", recognising that the final part of the definition is not necessarily inherent in the word to be defined, then it follows that we should examine where "wealth" can be made from living organisms or their components. Manufacturing *industry* is a prime generator of wealth but it should also be recognised that wealth can be derived from *social* gains which are often instigated by the action of government.

To define "government" in the present context is to describe the various agencies which sponsor, promote and support Biotechnological activity. In brief these may be summarised as:

> DES via the UGC to university teaching and via ABRC to the Research Councils for University Research and some Research Institutes. Various Ministries (DoI, MAFF, DHSS . . .) operate Research Institutes in addition to those run by the Research Councils. The BTG interfaces between the Research operations and *existing* industry, although the arrival of Celltech with Planttech (?) in the wings may indicate a more aggressive role. A Committee has been set up to coordinate the activities of the Research Councils in Biotechnology (IRCCCOB) and an additional committee set up to coordinate activities between Ministries, BTG and IRCCCOB, presently chaired by the Government Chemist Dr R F Coleman (ICBT).

Note (1) There are no agencies with "Technology" in their title. (Øf. Japan government agencies as presented in Appendix I, Diagram I, in which there are three, two of which have representation at *Prime Ministerial* level.)

(2) Much of the *biotechnology* effort is presently organised by *Science* Research Councils, the ramifications of which will be considered later.

OPERATING PREMISES

1. Industry will search out, examine and exploit every avenue which has the potential of yielding a profit.

2. The government (DES–UGC) has already recognised its responsibility for education and training in the the basic *sciences* which provide only a part of the education of a biotechnologist.

AREAS FOR GOVERNMENT INVOLVEMENT IN BIOTECHNOLOGY

1. Generating the enabling Science.
2. Generating the enabling Technology.
3. Generating social wealth.

Memorandum Submitted by Dr R E Spier

Most people would accept that much of the effort in the basic bio-sciences (ie. work to generate the knowledge and understanding of the way biological systems function and the methods which can be used to modify and control them) is presently well in hand. However, this cannot be said of the development of Technology. This situation is thrown into sharp relief when a comparison is made between the UK Government and the Japanese Government activities in the area of technology development (cf Appendix I). The present system of funding *technology* developments via *science* research councils may require re-examination.

The third role of government is to generate social wealth. This activity could be antithetical to the activities of established industry or it could be that industry cannot envisage generating sufficient profit from satisfying a minority interest. Examples of such activities are:

(1) A vaccine which (a) decreases health service costs, (b) results in more days at work, and (c) decreases the weight of infection (which cycles back to (a), results in a social gain which could be many times more than that which could show up as industrial profit.

(2) The development of new animal species which can be productive in the absence of antibiotics or hormones.

(3) The generation of plant species which can be productive in the absence of fertilisers and insecticides.

Problems

It is most unlikely that industry will come forward with its *real* problems because (a) this reveals a weakness, (b) secrecy is lost, and (c) exclusivity jeopardised. Furthermore, it is well aware that if it solves such problems in house, then this would give it a marked competitive advantage and could lead to a profit bonanza.

Biotechnologists outside industry are faced with considerable problems also. Their profession is multidisciplinary, which means that when they make grant applications they quite often get passed from one agency to the next as no one agency has a remit for technology. They are also *technologists* who seek to improve equipment, process and organism performance and where yield, cost, efficiency and control are the overriding considerations.

Also, there is a conspicuous absence of a defined and accepted National Strategy or Plan in those areas of biotechnology which can be expected to increase social wealth but where industry does not see a profitable market in the short term.

Theoretical Approach to a National Strategy for Biotechnology

In order to develop a National Strategy, the following activities are necessary:

(1) Project Nomination, (2) Project evaluation, (3) Assignment of Priority and Funds, (4) Execution, (5) Monitoring and (6) Project re-evaluation (ie. return to Step (2)).

The Marriage of Theory with the World we live in

The Interdepartmental Coordinating Committee (ICBT) under the Chairmanship of Dr R F Coleman, has recently been formed. This fulfils one of the prime recommendations of the Joint Working Party Report of Biotechnology (Chairman Dr A Spinks) (R2 p.9). If ICBT accepts as its remit another of the recommendations from the Spinks report (4.9) ". . . the Steering Group should initiate desk studies and build up a list of projects for which grant applications should be sought", then sector (1) of the theoretical plan above could be achieved.

However welcome such pro-active effort would be, it is vital that it be done *with the involvement and active support of all the relevant sectors of the scientific and technological community.*

Appendix I to the Memorandum Submitted by Dr R E Spier

To obtain the views and support of the scientific, technological, industrial and commercial sectors of the community it may be necessary to develop *new agencies* to solicit ideas, programmes and projects which could be of strategic importance to the country. It could be that in the area of biotechnology, the BCCB could fulfil this role although it would seem from its present mode of operation that it conforms more to the requirements of the European Federation of Biotechnology than to an organisation which comprehensively represents British biotechnologists. Such agencies could feed into the ICBT (or its equivalent in other areas of endeavour).

Also, it is of critical importance that the proposed projects are examined at the *highest ministerial level.* In Japan, the *Prime Minister* chairs the committee which selects projects for execution (Appendix I). So in order for the nominated projects in the UK to be evaluated as a matter of national strategy, it is necessary to bring them to the attention of the Departmental Minister and indeed the Prime Minister also. I suggest that the appropriate committee be set up to promote these ends.

Finally, the development of technology is an activity in its own right. It involves both reactor design and process delineation. It is orientated to the manufacture of products and the procedures which are used to obtain such ends have a discipline and a logic which require special training and experience. For these reasons I hold that it is in the interest of the nation to institute a *"Technology Development Council"* to operate along the lines of the present Research Councils.

Summary of Recommendations

1. Agencies be set up to involve the relevant scientific and technological community in the delineation of projects in areas which could increase social wealth and which would be unlikely to increase industrial profit in the short term.

2. The decisions on which projects to execute should be taken at the highest level, preferably involving the *Prime Minister.*

3. A *Technology Development Council* be instituted and funded to promote and sponsor technological development not only in the field of biotechnology but in other areas of technology also.

APPENDIX I

THE ROLE OF THE JAPANESE GOVERNMENT IN BIOTECHNOLOGY RESEARCH AND DEVELOPMENT

Dr M D Rogers, First Secretary, Science and Technology Department, British Embassy, Tokyo

A Paper to be read at the conference on biotechnology organised by the Biotechnology Group of the British Coordinating Committee for Biotechnology in June 1982

reproduced also in Chemistry and Industry, 7 Aug. 1982

Formulation of Science Policy in Japan

Three main bodies are concerned with the formation, implementation and coordination of science policy in Japan. The Science Council of Japan consists of members directly elected by scientists in Japan and is often dubbed "the parliament of scientists". It is independent of the administration but is government financed. Its primary functions are to provide independent advice to government and to act as a consultative body on science policy for government. The various committees of the Science Council of Japan (JSC) ensure that all the areas of science and technology are kept under review. Recommendations by the JSC are considered by the Council for Science and Technology (CST).

Appendix I to the Memorandum Submitted by Dr R E Spier

The CST is part of the Prime Minister's Office. It is chaired by the Prime Minister and has eleven members (one of whom is the President of the JSC). The CST is concerned with establishing general science policy for Japan, considering recommendations made by JSC and promoting studies on nationally important problems. The CST passes recommendations to the various ministries for executive action. Finally the Science and Technology Agency (STA) frames science policy in the form of national plans, promotes "Big Science" (space, atomic etc.) and is nominally responsible for coordinating the various activities taking place in the various ministries.

Since the inauguration of the JSC about 600 recommendations have been submitted to government and most of these have been implemented in one form or another. Biotechnology is a good example. This was the subject of a number of early recommendations by JSC. In 1971 the CST stressed the importance of promoting life science as a national policy and in 1973 the Committee for the Promotion of Life Science was established by the STA. This committee manages STA's own programmes in the biotechnology area and coordinates the work taking place in other ministries. There are similarities with the UK's Advisory Council on Applied Research and Development (ACARD) in the working of CST. However, ACARD did not study biotechnology until 1979 producing its report in 1980, roughly 7 years behind the Japanese.

The Scale of Government Involvement in Biotechnology R & D and the Main Government Centres

As indicated earlier, Government support for biotechnology dates from the beginning of the '70s. The Science and Technology Agency initiated the new government biotechnology programmes by establishing a Committee for the Promotion of Life Science in 1973. (The programmes are described as "new" since fermentation technology is a very old industry in Japan where many foods are based on fermentation processes. The Government Fermentation Institute for example, was established in 1940 but there are very many older institutions concerned with brewing or Zymotechnology!) Since then, the scale of Government support for biotechnology R & D has steadily increased. Support in 1981 for Life Science in general is estimated at a minimum of Yen 50,000 million and if one considers only the more restricted areas which are currently referred to as biotechnology the support was of the order of Yen 5,600 million in 1981. (i.e. approximately £12·4 million.) Government financial support has received fresh impetus in the last year with the announcement of the Ministry of International Trade and Industry's (MITI) biotechnology national projects. These new projects are the Biomass Development Project concerned with alcohol production (7 years from 1980—total budget Yen 12,300 million) and the Next Generation Industries national project which has three biotechnology themes (10 years from 1981—total budget in the biotechnology sector is in excess of Yen 30,000 million). The main Ministries involved with biotechnology R & D are:

the Ministry of International Trade and Industry

the Ministry of Agriculture, Forestry and Fisheries

the Ministry of Health and Welfare and

the Ministry of Education.

These are shown on the organisation chart. [Diagram 1.] The Science and Technology Agency has two roles. It is responsible for policy and inter-ministry coordination and it carries out its own R & D programme in the field of biotechnology. Inter-ministerial rivalries exist even in Japan and for this reason some people question the effectiveness of STA's coordination role. Nevertheless, in my opinion, it is fairly effective in the field of biotechnology not least because STA was involved from the beginning with its own programmes and because it has taken a central role in the setting of R–DNA regulations. As the House of Lords Select Committee on Science and Technology has indicated in its recent report on Science and Government a strong central body is required to provide science and technology advice, to establish national science and technology strategy and to help coordinate departmental efforts in these fields. In Japan the STA is attempting to carry out just these functions.

Appendix I to the Memorandum Submitted by Dr R E Spier

Science and Technology Agency Programmes

The STA Life Science Programme is directed by the Committee for the Promotion of Life Science while project management and budgetary control is exercised by the Life Science Promotion Department based in the Institute of Physical and Chemical Research. (This Institute is not a Government R & D laboratory. However, the majority of its funds are provided by STA.) There are currently 15 projects ranging from the development of advanced bioreactors to safety of R-DNA research and natural drugs. Expenditure in 1981 was Yen 640 million. Where the research is carried out in industry, the company concerned contributes 50 per cent of the project cost. There are a number of active projects under the STA's Life Science Programme. Some of the more significant projects are:

(a) The Ageing Mechanism and its Control

(b) Studies of Plant Hormones and their Production: Studies of Insect "Hormones" (Pheromones)

(c) Bioreactor Studies

(d) Recombinant DNA Studies

Two aspects of the work of STA will be discussed in greater detail, the bioreactor programme and the genetic engineering control regulations.

The Bioreactor Development Programme

(a) *Background*

The Government decision to promote life sciences in the early 1970's resulted in the creation of a specialist committee to recommend research and development projects. Professor Wada of Tokyo University was appointed to this committee and was instrumental in the selection of the research objectives. It was decided that the aim should be to select a topic which would raise the general level of science and technology in Japan rather than support activities, such as immobilized cell technology, which were already in progress. Hence the objective of studying the biochemical reaction circuits within living organisms in terms of their reactive elements, the enzymes, and their control mechanisms. The aim of this study is to develop advanced bioreactors ("Second Generation" bioreactors—existing fermenters being "first generation" bioreactors) which Professor Wada has referred to as chemical robots.

Two types of advanced bioreactors are being developed. A synthesis bioreactor—able to synthesize whatever substance is required from raw materials and enzymes—and a diagnosis bioreactor which by utilizing reactions between enzymes and specific compounds would be of tremendous value in medical diagnosis. The latter bioreactor is a shorter term project than the former. The projects started in 1977. A flow chart for the energy reproduction system for the bioreactor is shown. [Diagram 2.] The development of a successful ATP regeneration system was recently announced by the project team.

(b) *Project Membership*

Industrial participation was invited from a range of companies skilled primarily in chemical technology rather than traditional fermentation technology. (The companies concerned were conscious of increasing competition from the NIC's (Newly Industrialised Countries) and were thus committed to a policy of moving technically up market. Interestingly one of the latest companies to join STA's Life Science Project Group is Daini Seikosha—makers of Seiko watches—their interest is clearly related to competition from Hong Kong, for example, which makes about 80 million watches per year at about half the Japanese cost. The interdisciplinary approach which has been encouraged has been very productive in a project which includes computer control, biochemistry and chemical systems design.

Appendix I to the Memorandum Submitted by Dr R E Spier

(c) *The Polypeptide Typewriter—Bioreactor Project Phase* 2

The basic research on the synthesis bioreactor is now almost complete and the project is moving into applications research. The goal of the applications research is to produce a "polypeptide typewriter" (PPT) by 1983–84. The PPT is a programme controlled chemical reaction system which bonds specified amino acids from among 20 types in a specified sequence. The PPT is expected to be able to synthesise substances such as insulin with known amino acid sequences.

(d) *Bioreactor Project Phase* 3

The ultimate aim for the synthesis bioreactor plus PPT is to produce a system incorporating artificial intelligence and appropriate data bases which can select by trial and error polypeptides of optimal biological activity from among a variety of polypeptides. Genetic engineering technology will then be used to mass produce the optimum product designed by the PPT. The PPT and genetic engineering are thus complementary technologies. In Professor Wada's words the PPT "writes beautiful sentences" while genetic engineering "prints these for mass circulation". Phase 3 will follow on from Phase 2 in the latter half of the 1980's.

Genetic Engineering Control Regulations

The Science and Technology Agency is responsible for Japanese guidelines for the control of genetic engineering. Current guidelines are modelled on the first USA regulations. Although these have been partially amended three times since 1977–78 they are still fairly severe in their restrictions. The situation is not straightforward in that there are separate but sub-ordinate regulations in other ministries—notably the Ministry of Education. The employers' organisation is also currently framing regulations for industrial safety with respect to genetic engineering! The whole matter is currently under investigation with the intention of producing new national standards which reflect the latest findings on genetic engineering hazards. These new regulations will probably be issued in May or June of this year.

Work with organisms which have been "cleared" by the relevant expert committees is relatively straightforward but work which involves new experiments or "new" micro-organisms requires a lengthy approval process.

The STA is building a national genetic engineering facility at Tsukuba Science City with a P4 class laboratory. This will be run by the Institute of Physical and Chemical Research and a director has now been appointed. There will be about 100 researchers. It is interesting to note that there are problems associated with building this facility because of local opposition groups who fear that it may be associated with such things as biological warfare or represent a local hazard.

Ministry of International Trade and Industry (*MITI*) announced a major national programme in 1981 which was named The Next Generation Industrial Foundation Technology Development System! This is a 10 year programme (which was inaugurated on the 1st October 1981) with an estimated 10 year total budget of Yen 104,000 million. About one quarter of this money will be spent on biotechnology programmes.

The programme divides into six specific themes ranging in 10 year cost between Yen 5,000 million and Yen 15,000 million. There are six themes in innovational materials technology (ceramics, polymers and composite), three biotechnology themes and three semiconductor technology themes.

Biotechnology Themes

The biotechnology themes are clearly aimed at establishing biotechnology mass production techniques. The three themes are broadly:

(a) Bioreactor Development

(b) Recombinant DNA technology

(c) Large scale mammalian cell culture

Appendix I to the Memorandum Submitted by Dr R E Spier

The outline programme consists of a three year feasibility study followed by a 7 year practical applications development project. Industry is being involved on a long term basis and all the major companies in the project have joined the research and development association which MITI has established (Mitsubishi Chemical, Kao Soap, Mitsui Petrochemicals, Kyowa Hakko, Ajinomoto, Takeda, Sumitomo, etc). The main government laboratory in this programme is the Fermentation Research Institute (AIST/MITI) at Tsukuba.

The essential distinction between the STA biotechnology projects and the MITI biotechnology projects is that the former concentrates on medical aspects and longer-term advanced bioreactors, whereas the latter is mainly concerned with fine chemicals, alternative routes to petrochemicals, fertilizers, reduction and oxidation reactions using enzyme technology, recycling co-enzymes etc—and in general applications of biotechnology to the chemical industry including mass production problems. Thus it is clear that the MITI projects are strongly influenced by Japan's energy situation. Project details are not available yet but they will include the following aspects.

Bioreactors

Development of computer controlled bioreactors for mass production applications including reduction bioreactors and co-enzyme recycling studies.

Large Scale Mammalian Cell Culture

Development of cheap effective non-saline media. Development of large scale systems for pharmaceuticals. Selection of the most suitable cells (lymph cells and liver cells are of particular interest).

Recombinant DNA technology

Development of new host-vector systems—particularly thermophylic systems; Studies of yeast; Large-scale micro-organism surveys (screening); Development of improved systems for chemical production—oxidisation reactions. Production of enzymes etc outside the cell.

Biomass

The other main area of MITI support for biotechnology concerns biomass. The Biomass Policy Office was established in May 1980 as part of the Basic Industries Bureau of the Ministry of International Trade and Industry. The Biomass Policy Office is concerned with establishing the feasibility of Biomass Utilisation in Japan and identifying the most promising development lines.

The first year's programme established that two areas are the most economically viable:

(a) Waste utilisation—this is clearly the main resource, particularly methane production from domestic waste. The utilisation of cultivated plants cannot be justified economically.

(b) Cellulose utilisation—this is the most promising area and has become the main project. Economical decomposition has not been established but the development of this technology is considered essential, i.e.

Cellulose——Sugar——Alcohol

Gasification of wood is considered an interesting possibility and MITI is carrying out feasibility studies.

Biomass Project Activities

These are carried out by the 22 member companies of the Biomass Research Association (petroleum, chemical and fermentation). The member companies propose programmes which are integrated centrally and subsidised by an MITI contribution of 75 per cent. The Biomass programme extends over 7 years from 1980.

Appendix I to the Memorandum Submitted by Dr R E Spier

As the resources are relatively small, transport costs make most processes uneconomic Consequently the facilities are in general small in scale and commercialisation may be difficult. The main R & D projects are:

(a) Development of continuous alcohol fermenters using the membrane process.

(b) Development of high temperature and high alcohol resistant yeast strains. (Reduction of alcohol distillation costs.)

(c) Cell fusion technology.

The 1980 total budget was Yen 1,367 million and the 1981 budget was Yen 1,791 million. The total projected cost is in excess of Yen 12,300 million (not all projects included) of which MITI is contributing 75 per cent.

Ministry of Agriculture, Forestry & Fisheries Project

The Biomass projects of the MAFF which commenced in 1981 are concerned with making the most effective use of biological resources. The projects do not include studies of large-scale energy systems or alcohol as these are covered by current MITI projects. A very important aspect is the utilisation of waste biological material. The project activities inevitably cover a very wide field from process plant to enzyme technology to agriculture. However, the MAFF project flow chart (the "grand plan") which is shown [diagram 3] indicates the inter-relations between the various project activities. The budget for 1981 was Yen 250 million and the total project is planned to run for ten years. The original planned budget was Yen 1,000 million per year for ten years. However, spending in year one was only Yen 250 million and the expected budget for 1982 is approximately Yen 300 million (24 per cent increase). The final total budget might be of the order of Yen 5,000 million. Most of the R D and D will take place in MAFF laboratories but there will be some co-operation with industry and university departments.

Biomass Conversion

Essentially the MAFF Biomass Conversion Project is the conversion of raw material to useful products:

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                                    FOOD
                                    ENERGY
RAW MATERIAL——CONVERSION——ANIMAL FEED
                                    MEDICINES
                                    ETC
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Brief details of the various project stages are as follows:

Raw Material

Studies of existing agricultural resources and waste from food industry (tofu, crushed oranges, soybean and waste protein in general): Studies of new indigenous sources—particularly wood utilisation—and new resources not currently cultivated in Japan—possibly sweet sorghum from the USA: Evaluation of new agricultural systems (marine, forest, etc): Feasibility trials.

Pretreatment

As in all waste treatment the economics are strongly affected by collection, transport and pretreatment methods. Collection and transport technologies will be evaluated together with biological, physical and chemical pretreatment techniques.

Treatment/Conversion

Recombinant DNA technology will be studied as special project support for the biomass projects. There is particular interest in increasing enzyme yields in fermentation plants. Utilisation of animal waste materials for methane production in small areas or "diffuse" systems (essential difference from MITI projects). Utilisation of micro-organisms in the conversion of waste agricultural materials to food, animal feed, medicines, food additives

APPENDIX I TO THE MEMORANDUM SUBMITTED BY
DR R E SPIER

etc. Single-cell protein is of interest but the combination of government regulations and public attitudes makes this a low priority area.

SYSTEM EVALUATION

Construction of pilot plants in local areas.

TECHNOLOGY IMPROVEMENT

Bioreactor and enzyme technology studies: Pretreatment technology improvement: Energy conservation studies: Membrane technology studies.

CONCLUDING REMARKS

I hope that this paper will have given you some idea of the scale and scope of Japanese Government support for biotechnology. In conclusion I would like to emphasise three general points:

(a) *Government Technological Strategy*

Effective strategy cannot be formed by government in isolation. It must be produced via a consultative process. Although much has been made of the term *Japan Inc* in Western comments on Japanese success, Japan is not primarily an autocratic nation as far as industrial policies are concerned. Strategy is formed by a "bottom-up" process in Japan and this is facilitated by the close relations which exist between Government and industry. Thus although it may take a little longer to formulate strategy than in some other countries, agreement to the strategy will have been obtained from all parties prior to its formulation and hence its implementation is much more effective. Nevertheless a central body is necessary to initiate the consultative process, to ensure that this is as effective as possible and that all options are considered, to maintain momentum, to frame the conclusions and to co-ordinate action. Japan has just such a body—the Science and Technology Agency.

(b) *Co-ordination of Government Technological Programmes*

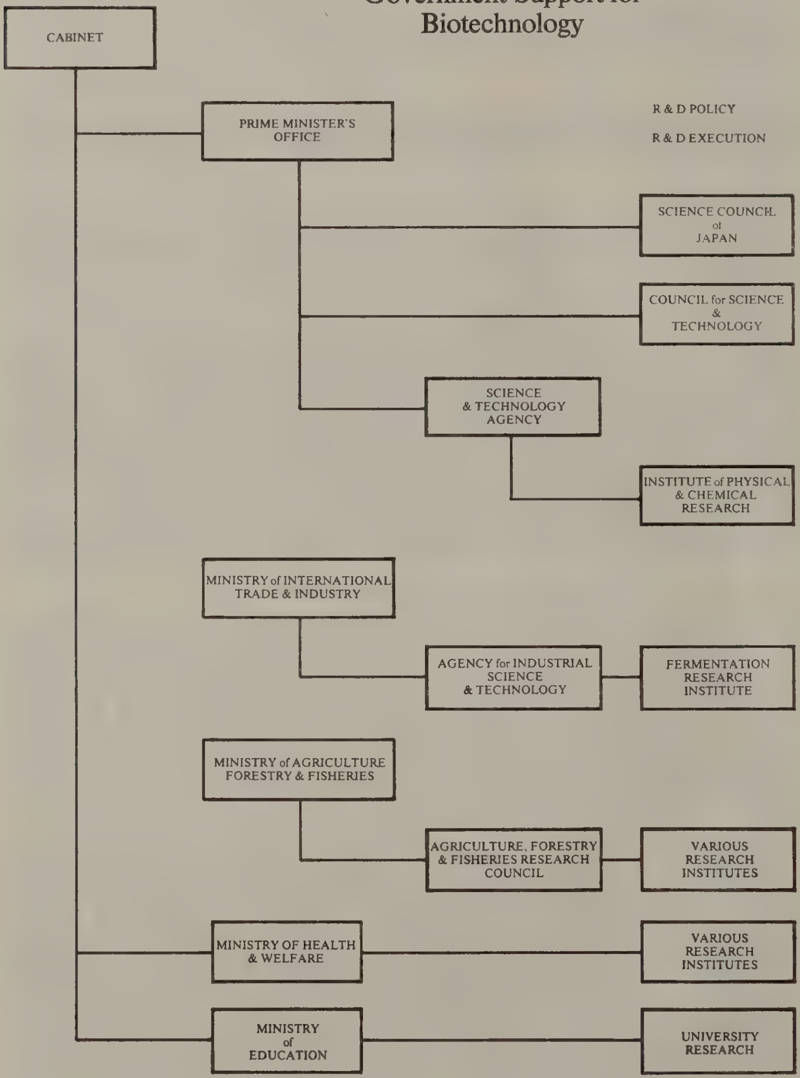
In implementing large interdisciplinary technological programmes such as biotechnology (or energy technology) several ministries are inevitably involved. Sometimes the division of work will be clear cut but this is often not the case, as for example, in R-DNA research or bioreactor development and overlaps will occur. Hence a *non*-ministerial body is required to co-ordinate programmes and reduce interministerial rivalry and programme overlaps. This role is also undertaken by STA and a special fund is used for the co-ordination and promotion of such multi-ministry technical programmes. As I indicated earlier there are several views of STA's effectiveness in this role but there cannot be any doubt of its necessity.

(c) *Finance*

There is no doubt that these programmes are large and well funded. However, too much should not be made of the government financial contribution to the R & D programmes. Of greater importance is the industrial involvement and commitment. Japanese Government investment in previous highly successful national electronics and computer projects was more than matched by industrial investment. Inter-company competition in Japan is intense and is probably a more important factor in the success of technical development programmes than government investment *per se*. The importance of such government programmes lies in the framing of mutually agreed strategies and in the *timely* promotion of the necessary advanced technologies (the "seed corn" policy). Industry having been involved from the beginning is then in a prime position to benefit from these programmes.

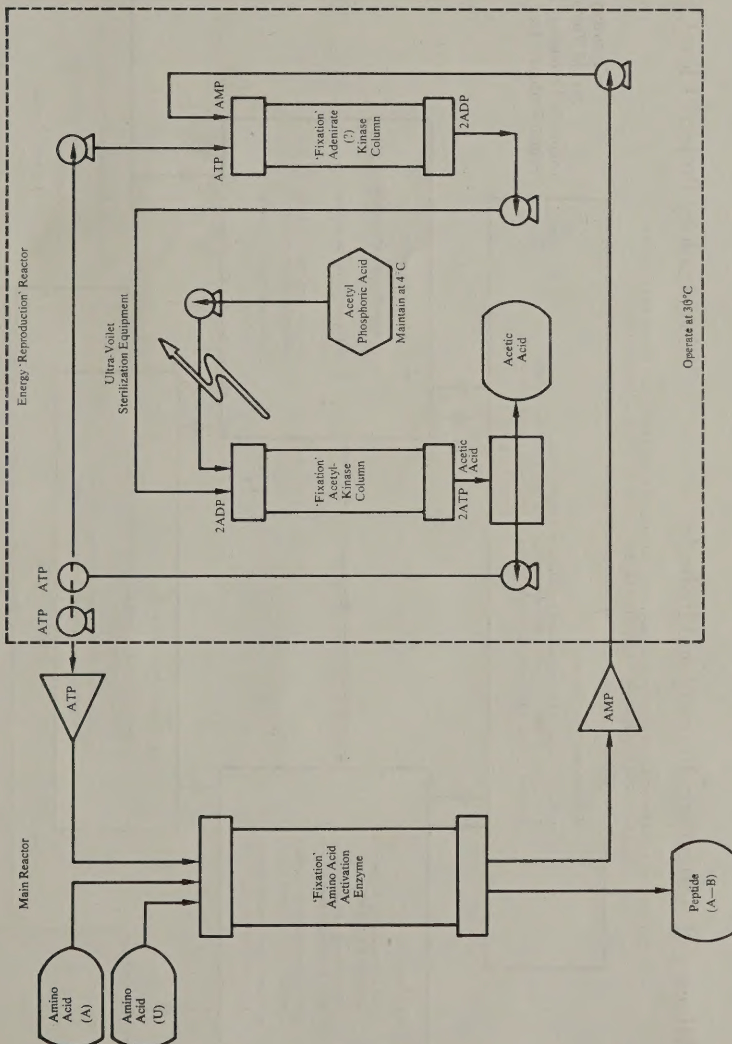
Appendix I to the Memorandum Submitted by Dr R E Spier

Diagram 1 — The Main Organisations Involved in Japanese Government Support for Biotechnology

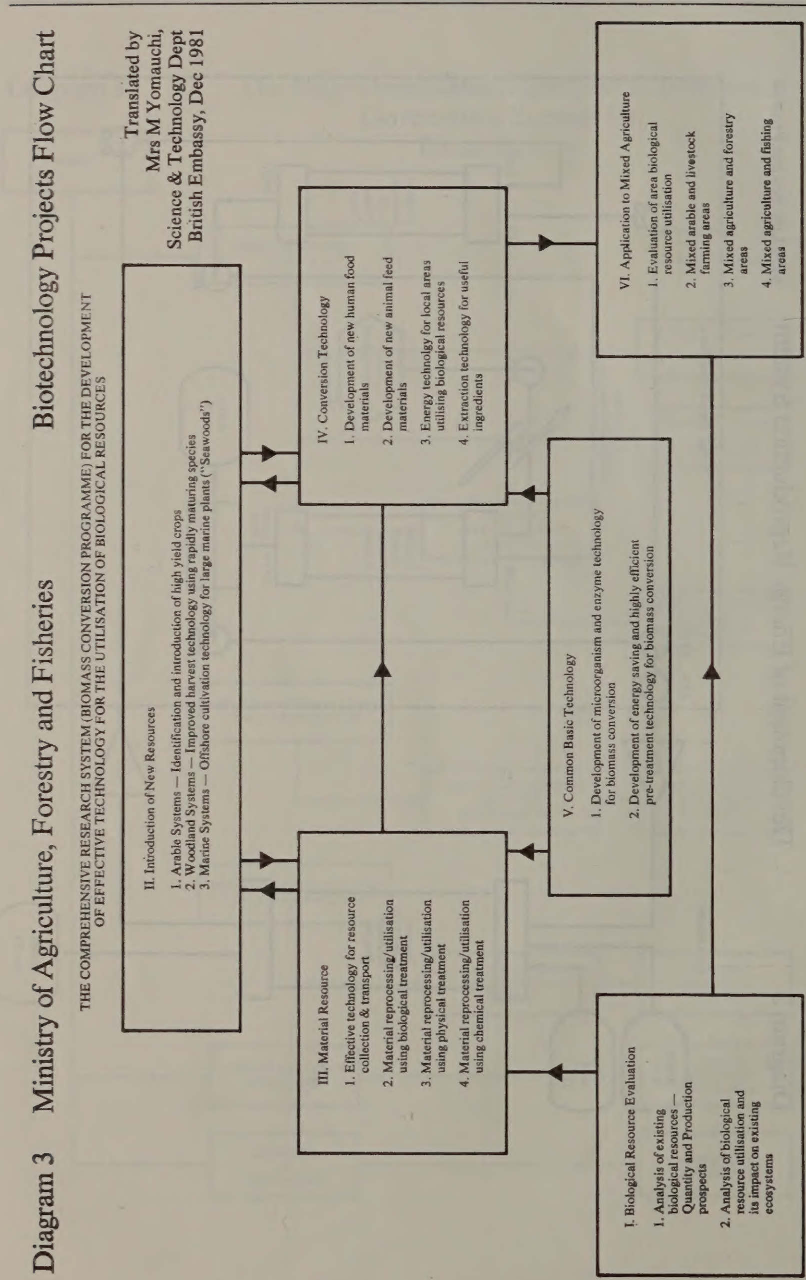


APPENDIX I TO THE MEMORANDUM SUBMITTED BY DR R E SPIER

Diagram 2 Development of Energy Reproduction System STA Life Science Projects



APPENDIX I TO THE MEMORANDUM SUBMITTED BY DR R E SPIER



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